Forest Research
Technical Report
Vancouver Forest Region
2100 Labieux Road, Nanaimo, BC, Canada, V9T 6E9, 250-751-7001

TR-017 Ecology March 2002

An Operational Trial to Evaluate the Effectiveness of Using Modified Bucking/Yarding Practices in Coastal Old-Growth Stands to Maximize Coarse Woody Debris Levels in the Setting: Establishment Report

Prepared by
G. Davis and A. Nemec
for the Vancouver Forest Region Coarse Woody Debris Working Group

Research Disciplines: Ecology ~ Geology ~ Geomorphology ~ Hydrology ~ Pedology ~ Silviculture Systems ~

Gerry Davis
Research Ecologist
Vancouver Forest Region
BC Ministry of Forests
2100 Labieux Road
Nanaimo, British Columbia V9T 6E9
250-751-7001

Amanda F. Linnell Nemec
International Statistics and Research Corp.
PO Box 496
Brentwood Bay, British Columbia V8M 1R3
afln@isr.bc.ca

Davis, G. and A. Nemec. 2002. *An Operational Trial to Evaluate the Effectiveness of Using Modified Bucking/Yarding Practices in Coastal Old-Growth Stands to Maximize Coarse Woody Debris Levels in the Setting: Establishment Report.* Prepared for the Coarse Woody Debris Working Group. Research Section, Vancouver Forest Region, BC Ministry of Forests. Nanaimo, BC. Technical Report TR-017. 64 pp.

http://www.for.gov.bc.ca/vancouvr/research/research_index.htm

106-05559/

TABLE OF CONTENTS

EXECUTIVE SUMMARY 3
KEYWORDS 3
ACKNOWLEDGEMENTS 3

1 INTRODUCTION 4

2 OPPORTUNITY TO MAXIMIZE CWD RETENTION AT THE TIME OF HARVEST 5
2.1 Potential Sources of CWD 5
2.2 Options for Maximizing CWD in the Setting, Post-Harvest 7

3 STUDY OVERVIEW: MODIFIED BUCKING AND YARDING PRACTICES 8
3.1 Overview 8
3.2 Study Objectives: Economic and Dead-Wood Components 8

4 PROJECT DESIGN AND IMPLEMENTATION 9
4.1 Site Selection 9
4.2 Site Description 9
4.3 Stand Description 9
4.4 Layout 9
4.5 Bucking and Yarding Practices 11

5 METHODS 14
5.1 Definitions 14
5.2 Cruise Measurements 15
5.3 Measurements of Coarse Woody Debris and Stumps 15
5.4 Site Index and Tree Age 16

6 ANALYSES 17
6.1 Pre-Harvest Analyses 17

7 RESULTS 19
7.1 Selection of CWD Diameter and Length Classes 19
7.2 Site Overview 20
7.3 Operational Cruise Summary 21
7.4 Total Gross Site Volume, by Stratum and Log Grade 23
7.5 "Potential" Sources of Post-Harvest CWD: Attributes of Pre-Harvest CWD and Low-Value/Non-Merchantable Wood in the Stand 24

8 DISCUSSIONS AND CONCLUSIONS 29
8.1 Potential Sources of CWD 29
8.2 Block Comparisons 33
8.3 Literature Comparisons for Dead Wood 33
8.4 Post-Harvest Surveys 35
8.5 Towards the Development of Quantitative CWD Management Guidelines: Future Survey Needs 36

9 LITERATURE CITED 41

10 GLOSSARY 43

APPENDIX A. DEFINITIONS OF SPECIES-SPECIFIC COASTAL LOG GRADES 45

APPENDIX B. OPERATIONAL TRIAL TO EVALUATE THE USE OF MODIFIED HARVESTING PRACTICES IN COASTAL OLD-GROWTH STANDS TO MAXIMIZE COARSE WOODY DEBRIS LEVELS: DESCRIPTIONS OF THE BUCKING, YARDING, AND LOADING PHASES 48

APPENDIX C. SUMMARY OF CWD DENSITY AND VOLUME STATISTICS FOR BOTH STUDY BLOCKS, USING LENGTH AND DIAMETER CLASSES FROM THE LITERATURE 64

TABLES

Table 1. Utilization, as per cutting authority, for harvesting operations in Coastal British Columbia 6
Table 2. Timber utilization policies: Avoidable Waste Benchmark volumes 7
Table 3. Stand statistics: Operational Cruise Summary 10
Table 4. Broad timber types found at the study site 12
Table 5. Areas corresponding to site, Wildlife Tree Patch, and yarding method, by study block 12
Table 6. General schedule of activities 12
Table 7. Summary of pre-harvest strata 15
Table 8. Definitions of tree classes used by Weyerhaeuser and the BCMOF 16
Table 9. Compilation piece definitions 17
Table 10. List of attributes used to compare the study blocks prior to harvesting, and corresponding units of measure 18
Table 11. Comparison of total gross volume/ha of windfalls for Tree Class C: cruise taper equation versus Smalian equation of piece within plot 18
Table 12. Cumulative distribution frequencies for CWD length 19
Table 13. Cumulative distribution frequencies for CWD, large-end diameter 19
Table 14. Diameter and length classes for specific cumulative percentiles 20
Table 15. Examples of diameter classes used in the literature, and the corresponding cumulative diameter distribution percentages based on study results 20
Table 16. Total site density, by stratum 21
Table 17. Total gross site volume, by stratum 21
Table 18. Gross cruise a volume, by tree class and log grade: both study blocks combined 22
Table 19. Cruise net volume, by tree class and log grade: both study blocks combined 23
Table 20. Market value, by tree class and log grade: both study blocks combined 24
Table 21. % of total market value, by log grade and tree class: both study blocks combined 24
Table 22. Total gross site volume and net site volume, for all strata combined 24
Table 23. Total gross site volume partitioned, by tree class, stratum, and log grade: both study blocks combined 25
Table 24. % of total gross site volume, by stratum and log grade: both study blocks combined 26
Table 25. Density of CWD, partitioned by diameter and length classes 27
Table 26. Volume of CWD, partitioned by diameter and length classes 28
Table 27. Density of CWD, partitioned by diameter and decay class 29
Table 28. Volume of CWD, partitioned by diameter and decay classes 30
Table 29. Density of "potential" logs in standing trees, by log grade and study block 31
Table 30. Volume of "potential" logs in standing trees, by log grade and study block 32
Table 31. Potential large low-value/non-merchantable pieces in Tree Classes A, B, and D: differences in density and volume, by study block 33
Table 32. Examples of total, old-growth, dead-wood volumes reported in the literature. 34
Table 33. Total pre-harvest dead-wood volume, partitioned by structures (s) and merchantability: Example Coastal Summary Table 38
Table 34. Pre-harvest attributes and potential sources of large CWD: Example Coastal Summary Table 39
Table 35. Post-harvest CWD attributes for the dispersed stratum: Example Coastal Summary Table 40

FIGURES

Figure 1. Site overview 9
Figure 2. Conks 11
Figure 3. Frost crack 11
Figure 4. Windfall 11
Figure 5. Well-Decayed CWD 12
Figure 6. Site map (scale 1:5000) 13
Figure 7. Total gross site volume, by stratum and log grade. 25

EXECUTIVE SUMMARY

During helicopter harvesting of old-growth forests in Coastal British Columbia, two strategies have been successful in reducing yarding and hauling costs and dryland sort accumulations. These two strategies involve the following modified harvesting practices:

• Bucking on site to create higher value logs. In this approach, low-value/non-merchantable wood (e.g., Y and Z Grade) is bucked and left in the setting.

• Marking Z and Y Grade wood for the purpose of leaving on site. A scaler marks low-value/non-merchantable wood with paint after falling and bucking, but prior to yarding.

The added benefit of these modified practices is an increased retention of coarse woody debris (CWD), as low value/non-merchantable wood is dispersed throughout the harvested setting rather than accumulating at roadside or being removed.

In 1999, a multi-year operational study was initiated to evaluate the logistics, feasibility, and success of transferring procedures used in helicopter harvesting to other harvesting systems. The purpose of the study is to compare, for both conventional and modified harvesting practices, the operational costs as well as the post-harvest distribution and attributes of CWD over a range of sites.

Before embarking on the multi-year project, a pilot study was undertaken to evaluate the sampling protocol and the operational feasibility of applying these modified practices to other harvesting systems. The pilot site, chosen in 1999, was an old-growth site in the Montane variant of the Very Wet Maritime subzone of the Cedar Western Hemlock biogeoclimatic zone (CWHvm2). This site was to be cable harvested. The pilot site was divided into two blocks, one of which was harvested by conventional means and the other using the modified practices.

The review of the pre-harvest timber and CWD attributes for the pilot site indicates there is the potential to retain, at the time of harvest, CWD volumes comparable to the total volume of pre-harvest dead wood. It is expected, however, that only a portion of the total low value/non-merchantable wood volume will be left on site due to various operational factors—even in the block where Y and Z Grades of wood are bucked off at the stump and marked to leave.

The total volume of pre-harvest low-value/non-merchantable wood (standing and down) was not significantly different between the two blocks. However, there were a few significant differences in the distribution of this wood, which may or may not confound the detection of post-harvest differences. Total volume/ha of CWD was the main significant different between the two blocks. The significantly higher total volume/ha for the Mark-to-Leave Block reflects a higher density of larger-sized pieces. Further, the two blocks show a significant difference in the distribution of pieces by decay class. The Conventional Block has a higher proportion of small to midsize pieces in the Well-Decayed Class while the Mark-to-Leave Block had a higher proportion of larger pieces in the Moderately Well-Decayed Class.

Data from the 2001 post-harvest comparison of the two blocks will provide an opportunity to evaluate the effectiveness of using the modified bucking and yarding practices to increase CWD volume and maintain larger-sized pieces in the dispersed setting. The comparison will also highlight difficulties in implementing these practices, and indicate the cost of implementing the practices on an operational scale.

KEYWORDS

harvesting, mark-to-leave, coarse woody debris, coarse woody debris volume, log value, low-value wood, nonmerchantable wood, log scaling, bucking, yarding, costs, Coastal British Columbia

ACKNOWLEDGEMENTS

This project was undertaken under the auspices of the Vancouver Forest Region's Coarse Woody Debris Working Group. Funding for the pre-harvest component of this project was provided by the BC Ministry of Forests and Weyerhaeuser's BC Coastal Group.

The authors would like to recognize the interest and commitment of staff at Weyerhaeuser's North Island Timberlands Division during the field operations. Weyerhaeuser staff involved in the various aspects of the project include: Allan Beise, Ray Sumner, Mazz Battistuz, Rob Kine, Adrian Stevens, Don Watts, and Norm Harben. Ed Redlin of Azmeth Forest Consultants Ltd. was instrumental in ensuring the modified bucking practices and marking components of the project were completed properly. Further, the project could not have been completed without the involvement, interest, and commitment of Eric Phillips, Brian Bulley, and Craig Evans of the Forest Engineering Research Institute of Canada (FERIC).

The authors would like to thank the following reviewers for their insightful comments on various drafts of the report: P. Ott, D. Heppner, E. Phillips, D. Collins, N. Densmore, and J. Parminter. Kathi Hagan is gratefully acknowledged for the technical editing and layout of this document.

1 INTRODUCTION

Coarse woody debris (CWD) is an important structural component in forested ecosystems. The structural and functional roles of CWD are multi-faceted. CWD provides critical habitat for a myriad of organisms, many of which are connected by "functional pathways that are partially or completely unknown" (Torgersen and Bull 1995). Organisms linked to CWD include invertebrates, fungi organisms, many species of plants (especially bryophytes and lichens), and vertebrates (Maser et al. 1984; Harmon et al. 1986; Caza 1993; Bull et al. 1997). The amount, structure, and dynamics of CWD in forests can also influence nutrient cycling and site productivity, soil stability, global carbon storage, and provision of biological legacies—all of which are structural and functional links between present and future forests (Hansen et al. 1991; Harmon and Chen 1991).

In British Columbia, the management of CWD is a legislative requirement on private land, on a Tree Farm Licence or woodlot licence, and on Crown land other than in a Wilderness Area.[1] The *Forest Practices Code of British Columbia Act* requires CWD management objectives to be established in Forest Development Plans[2] and Silviculture Prescriptions[3]. Current CWD management is tied to the BC Ministry of Forests' timber utilization policy (BCMOF 1997; *Landscape Unit Planning Guide*, BCMOF and BCMOE 1999). Based on the Chief Forester's 1996 impact estimates on stand-level biodiversity, CWD management is to have no impact on operating costs or timber supply[4] (*Forest Practices Code Timber Supply Analysis*, BCMOF and BCMOE 1996).

While limited, available literature suggests that the long-term effects of timber harvesting and silviculture practices on dead wood (standing and down) are a reduction in dead wood volume and a reduction in piece size (Spies and Cline 1988; Spies et al. 1988; Maser and Trappe 1984; Carey and Johnson 1995; Reid et al. 1996; Green and Peterken 1997; Fridman and Walheim 2000; Anglestam 1977). These reductions are most pronounced where there is a long history of forestry (Anglestam 1977; Samulesson et al. 1994). For Swedish forests, Anglestam (1977) reported that dead wood comprised 30–40% of the total wood volume in unmanaged stands and declined to about 20% after one rotation. After several rotations of intensive fibre extraction dead wood volume was reduced to about 1% of the total wood volume. Samulesson et al. (1994) similarly report small amounts of dead wood and very few large-diameter pieces in managed forests in Poland, England, and central Sweden.

While the history of forestry activities is shorter in the Pacific Northwest, the projected scenarios are similar to those reported for European countries. The continued loss of dead wood under successive cycles of clearcutting was modelled by Spies and Cline (1988). They predicted that snag and log abundances would be 30% of the pre-harvest level at the end of the first 100-year rotation and 6% after the second. Inputs through logging slash and some dead tree mortality were included in the model. During the second 100-year rotation of the simulated, manipulated forest, total dead wood decreased from 24 tons/acre at the beginning of the rotation to only 5 tons at the end of 100 years, before harvest. This simulation produced few or no large pieces (>50 cm diameter) over one or two rotations (Spies et al. 1988). Similar projections have been made for eastern hardwood forests (Gore and Patterson III 1985; McCarthy and Bailey 1993).

In North America, available research results about the effects of harvesting on CWD (down wood) attributes are varied. Reported changes in total volume/ha or biomass following harvest include: increases (McCarthy and Bailey 1993; Torgerson 1999; Gore and Patterson III 1985) and small changes (Torgerson 1999; Lloyd 2001; Davis and Nemec 2001). In part, these differences reflect factors such as timber type, stand age, harvesting objectives, and prior disturbance history. However, the above studies consistently report a shift in piece-size distribution. Most studies report an increase in total piece density with reductions in diameter and/or piece length that are related to harvesting (Gore and Patterson IIII 1985; McCarthey and Bailey 1993; Torgersen 1999; Davis and Nemec 2001). Research of this type is limited in Coastal British Columbia forests.

Owing to the sparse data about CWD in either managed or unmanaged forests, quantitative guidelines for its management in British Columbia are currently unavailable. Guiding principals and management considerations to improve CWD retention within the context of BC Ministry of Forests' timber utilization policy (BCMOF 1997) are outlined in a recently released short-term strategy for managing CWD (BCMOF 2000d). According to this document, there is an urgent need to assess the status of CWD relative to current harvesting practices, as well as a need to initiate pilot studies to identify and evaluate approaches for increasing CWD retention at the time of harvest. Over the past few years, various projects have been initiated throughout British Columbia to address the shortfall in CWD data. Projects are varied in scope but include:

1. pre-harvest inventories of dead wood and/or CWD (e.g., Davis et al. in preparation),
2. post-harvest inventories of CWD (e.g., Lloyd 2001),
3. research on specific wildlife habitat requirements (e.g., Hartwig 1999), and
4. research on the feasibility of alternative approaches to maintaining CWD in the setting through modified operational practices (e.g., Huggard 2000).

The following is a report about the establishment of the pilot phase of a multi-year (replicated) study. The purpose of the

[1] Forest Practices Code of BC Act, Provincial Forest Use Regulation, Sections 2(1), 4(a) and (b), and 7(1).
[2] Forest Practices Code of BC Act, Operational Planning Regulation, Section 18(1)(u).
[3] Forest Practices Code of BC Act, Operational Planning Regulation, Section 39(3)(m).
[4] The 1.8% timber reduction allocated to stand-level biodiversity in the 1996 timber supply analysis (BCMOF and BCMOE 1996) was assigned to Wildlife Tree Reserves.

study is to compare the harvesting economics and the resultant CWD attributes achieved through conventional operational bucking and yarding practices to those achieved through a modified method that leaves low-value wood in the setting rather than at the roadside or landing. This report presents the pre-harvest dead wood results for the pilot study. A comparison of pre-harvest and post-harvest data will be available in the spring of 2002. The progress report for the harvesting economic component is available from the Forest Engineering Research Institute of Canada (FERIC).

2 OPPORTUNITY TO MAXIMIZE CWD RETENTION AT THE TIME OF HARVEST

2.1 Potential Sources of CWD

Under the timber utilization policy for Coastal British Columbia (BCMOF 1997), potential sources of CWD that can be left in the harvested setting without the forest company incurring monetary billing **(Table 1)** include:

1. Live Y Grade logs (recorded in Residue and Waste Survey as avoidable and unavoidable residue).

2. Dead Y Grade logs from snags and down trees and CWD (defined in Residue and Waste Survey as Grade 5-Dead Lumber Reject, but not recorded).

3. Z Grade or Firmwood Reject logs (defined in Residue and Waste Survey but not recorded).

4. X-Grade-and-better logs[5] (recorded in Residue and Waste Survey as avoidable waste if not retained for safety reasons). (Refer to **Table 2** for information on avoidable waste benchmark volumes.)

5. X-Grade-and-better logs (recorded in Residue and Waste Survey as unavoidable waste if retained for safety reasons).

6. Dead down woody debris with size, quality, or decay features below the Z Grade criteria (not recorded in Residue and Waste Survey).[6]

7. Leave trees (dispersed/clumped) (not recorded in Residue and Waste Survey).

Technically, items 1, 2, 3, and 6 above are "optional" and can be utilized at the discretion of the Licensee depending upon market conditions. The Cutting Permit may specify the utilization of Y Grade logs with certain attributes. Under this scenario, failure to utilize these logs will result in the Licensee being billed at a rate of $0.25/m^3$. On the Coast, this scenario is a special case rather than a rule.[7] Item 4 is mandatory utilization, but is not billed for the first 35 m^3 in old growth nor for the first 10 m^3 in second growth (refer to Table 2). Item 5 is not mandatory utilization. Item 7 regarding leave trees is discussed below.

Log Grades. General definitions for the above log grades are provided in Appendix A; for more detail refer to the *Scaling Manual* (BCMOF 1999). Briefly, Live Y Grade logs are low value and are used for pulp. This grade is not billed but is charged to Cut Control, unless otherwise specified in the Cutting Permit. Dead Y Grade and Z Grade logs and dead down wood not meeting utilization standards are not monitored for utilization. Dead Y Grade logs can be greater than 50% sound, but, because of checking and rot, they are not recorded in a Residue and Waste Survey. The Z Grade log is generally less than 50% sound and has too much rot for use as pulp. Neither is charged to the Cut Control. Utility-Grade-and-better logs (X-Grade-and-better logs) may be classified as either avoidable waste or unavoidable waste. Avoidable waste is wood that meets the mandatory utilization criteria. In 1999, the benchmark avoidable waste volumes noted in Table 2 were incorporated into the timber utilization policy (BCMOF 1997) to mitigate low market value for marginal timber. The benchmark avoidable volumes are voluntary; they are not billed, but are charged to the Cut Control. The other source of X-Grade-and-better logs is the unavoidable waste. Unavoidable waste consists of X-Grade-and-better logs that are left on site for safety or environmental reasons.[8] This wood is charged to the Cut Control but not billed. The remaining dead down woody debris, which has no utilization value, is not tracked for either billing or Cut Control purposes because it is typically well below 50% sound and has size, quality, or decay features that prohibit its use even for pulp.

Leave Trees. Leave trees may be retained in the setting for various purposes including seed production, visual enhancement or to serve as Wildlife Trees. The retention of these trees is specified in the Silviculture Prescription and Cutting Permits. The retention of leave trees solely for CWD recruitment is not practised in British Columbia. Instead, CWD recruitment is indirectly linked to reserve strata such as Wildlife Trees (patches or individual trees) and Riparian Management Zones. For example, a Silviculture Prescription may specify that Wildlife Trees are to be retained—either dispersed throughout the cutblock or within a patch—with CWD recruitment listed as a secondary objective. The numbers and sizes of trees and associated volumes, all of which are important in determining the quantity and quality of CWD, are not specified. Moreover, even though trees within existing reserves represent a potential source of future CWD, they do not function as

[5] BCMOF internal memorandum, from Janna Kummi (Assistant Deputy Minister, Operations Division) to all Regional and District Managers, re: Timber Utilization Policy; 20 January 1999.
BCMOF internal memorandum, from Jim Gowriluk (Assistant Director, Resource Tenures and Engineering Branch) to All Regional Managers and All District Managers, re: Timber Utilization Policy; 22 January 1999.

[6] For the purpose of the pilot study, dead down woody debris has been assigned a Z Grade when it does not meet the criteria of a Y-Grade-or-better log.

[7] Bruce Markstrom, Cruising and Waste Technician, Vancouver Forest Region, BC Ministry of Forests, Nanaimo, BC; personal communication, June 2001.

[8] There is provision within the *Logging Residue and Waste Procedures Manual* (BCMOF 2000a) to classify mandatory utilization logs which have been marked in the field to meet CWD objectives specified in a Forest Development Plan and Silviculture Prescription as unavoidable waste. This wood would be charged to the Cut Control but not billed (Forest Practices Code General Bulletin 33).

Table 1. Utilization, as per cutting authority, for harvesting operations in Coastal British Columbia.

Residue and Waste class	Description	Log type and grade	Cut Control	Billable Rate
Waste Meets the quality and size requirements for utilization, as specified in the cutting authority.	**Avoidable** Waste wood volumes left on the ground that: a) could have been removed safely, b) were not physically obstructed, and c) were not inaccessible.	Saw Log: X-Grade-and-better.	Yes	Equal to current stumpage rate (excluding avoidable waste benchmark volume).
	Unavoidable Any portion of any grade that is physically obstructed or cannot be removed for safety or environmental reasons, or because it is inaccessible.	Saw Log: X-Grade-and-better.	Yes	Not billed.
Residue Meets the size but not the quality requirements for utilization, as specified in the cutting authority.	**Avoidable** Residue wood volumes left on the ground that: a) could have been removed safely, b) were not physically obstructed, and c) were not inaccessible.	Lumber Reject: Y Grade (optional).	Yes	Not billed if optional utilization and left on site, otherwise billed $0.25/m^3 if removed. Billed $0.25/m^3 if mandatory utilization, whether left or taken.
	Unavoidable Any portion of any grade that is physically obstructed or cannot be removed for safety or environmental reasons, or because it is inaccessible.	Lumber Reject: Y Grade (optional).	Yes	Not billed.
Other	**Not measured**	Dead Dry Lumber Reject: Dry Y-Grade 5. Firmwood Reject: Z.	No No	Not billed. Not billed.

CWD until they are dead on the ground. If trees within existing reserves are to contribute towards CWD, then a more integrated management strategy is needed, in particular, one that considers the link between Wildlife Trees and CWD. Achievement of this goal will require research on the mechanisms of CWD recruitment; development of strategies for optimizing the distribution of reserves; and a commitment to ensuring that the prescribed number and sizes of trees will fall throughout the rotation, either naturally (i.e., natural mortality and windthrow) or manually (Carey et al. 1996). The development of quantitative CWD management objectives over the near future will facilitate this process.

Currently in British Columbia, the achievement of CWD management objectives is tied to designated reserves of trees (e.g., Wildlife Tree Patches). The net down to the Allowable Annual Cut (AAC) for trees providing CWD recruitment is accounted for in the AAC net down for the reserve. Leave trees other than those in reserves (e.g., seed trees, low-value trees, trees in Silviculture Retention Patches) that are a potential source of CWD recruitment[9] are not retained because there is an associated reduction to the AAC determination. "Standing leave trees (specified in the Silviculture Prescription and Cutting Permit) are not charged to the Licensee's AAC or billed through the Cut Control. They are accounted for at the time of the Chief Forester's AAC determination. To the extent that trees are left standing on the block to address CWD recruitment, a deduction is made in the Timber Supply Analysis and is reflected in

[9] With direction provided on natural and/or manual felling throughout rotation.

Table 2. Timber utilization policies: Avoidable Waste Benchmark volumes. [a]

Policy	Stand age	Avoidable Waste Benchmark volumes, as of 1/99
Billed Wood Volume [b] Wood left on site in excess of these amounts is subject to billing.	Old growth	Dispersed and Accumulations combined: 35 m^3/ha (avoidable stumps, bucking waste, logs)
	Second growth	Dispersed and Accumulations combined: 10 m^3/ha (avoidable stumps, bucking waste, logs)
Re-Log Wood left on site in excess of these amounts may have to be removed from the site (re-harvested).	Old growth	Dispersed: 35 m^3/ha (X-Grade-and-better logs) Accumulations (at roadside and in piles): 100 m^3 (X-Grade-and-better logs)
	Second growth	Dispersed: 15 m^3/ha (X-Grade-and-better logs) Accumulations (at roadside and in piles): 50 m^3 (X-Grade-and-better logs)

[a] See the following sources for more details about timber utilization policies:
- BCMOF internal memorandum, from Janna Kummi (Assistant Deputy Minister, Operations Division) to all Regional and District Managers, re: Timber Utilization Policy; 20 January 1999.
- BCMOF internal memorandum, from Jim Gowriluk (Assistant Director, Resource Tenures and Engineering Branch) to All Regional Managers and All District Managers, re: Timber Utilization Policy; 22 January 1999.

[b] Applies to primary (first-pass) harvesting.

the determination. Therefore, the AAC may be slightly lower than it would be if no trees were being retained on the blocks."[10] The Timber Supply Analysis incorporates the leave tree volumes into the AAC determination. In the case of seed trees, for example, it is assumed that the seed trees will be removed during the rotation. If these trees are felled to meet CWD objectives, the volume associated with the seed trees will be unavailable for removal, and constitute a reduction in the AAC. The assessment does not, however, take into account the timber volume associated with the "fill-in" trees, which will be available for harvest at the end of the rotation.[11]

2.2 Options for Maximizing CWD in the Setting, Post-Harvest

Based on the above observations, there are three main tools that could be used on the Coast of British Columbia for increasing CWD retention in the dispersed setting at the time of harvest:

1. Reduce roadside accumulations[12] by bucking out Y Grade, Z Grade, and leaving this wood in the setting.

2. Protect existing dead down wood below the utilization standards.

3. Provide leave trees in reserves as a source of CWD during the rotation.

Coastal, old-growth, stands provide the best opportunity to leave low-value wood in the setting through modified bucking and yarding practices (e.g., bucking out low-value wood, marking which pieces to leave on site, identifying no-yarding areas) because of the high incidence of defect in the timber. Further, because CWD volumes are high and piece sizes are large in old-growth compared to mid-seral stages of development (Spies and Franklin 1988; Wells et al. 1998) there is more opportunity to maintain large pieces of CWD. Implementing these practices will be more challenging in cable-harvesting operations than in helicopter operations. Leave trees in reserves are also potential sources of CWD in old-growth stands, although further study is required to evaluate the effectiveness of reserves as CWD recruitment centers with regard to the distribution, frequency, and size of CWD inputs over multiple rotations, and to evaluate incremental costs.

In contrast to the old-growth stands, mature, second-growth Coastal stands have limited defective wood in the timber (Ruth and Harris 1975; Nagle 1980), and carry-over of CWD volume from the previous stand is at a natural low (Spies and Franklin 1988; Wells et al. 1998). Stem diameters in second-growth stands are generally smaller than those of old-growth

[10] M. Mana, RPF, Compliance and Enforcement Office, BC Ministry of Forests, Vancouver Forest Region, Nanaimo, BC; personal communication, May 2001.
[11] See Footnote 10.
[12] Current forest practices involve yarding of some non-merchantable logs to roadside for a variety of reasons: 1) because merchantability is not visible until the log is yarded to roadside; 2) to ensure the operation is not penalized for leaving merchantable logs on the setting; or 3) because worker training is inadequate. In addition, some low-value/non-merchantable material is loaded, trucked, sorted, and disposed of at the dryland sortyard. It is estimated that approximately 0.4% of volume put through dryland sortyards is roundwood that requires disposal (Forrester 1996, cited in Phillips 2001).

stands, thereby reducing opportunities to leave larger-sized pieces of wood.[13] In Coastal, mature, second-growth stands, leave trees and protection of existing large CWD, when present (i.e., through modified yarding practices such as designated trails around legacy pieces), represent the main opportunities to manage for CWD under the current timber utilization policy (BCMOF 1997). However, as mentioned above, the effectiveness of the former option requires further investigation.

3 STUDY OVERVIEW: MODIFIED BUCKING AND YARDING PRACTICES

3.1 Overview

In Coastal British Columbia, strategies are being sought to maximize the retention of CWD on timber-harvesting sites, because CWD is recognised as a critical component of forested ecosystems. In old-growth stands, two strategies have been successfully used in helicopter operations to reduce hauling costs and dryland sort accumulations, with the added benefit of maximizing the retention of low-value/non-merchantable wood in the dispersed harvesting setting. These two strategies involve the following modified harvesting practices:

- Bucking on site to create higher value logs. In this approach, low-value/non-merchantable wood (i.e., Z and Y Grades) is bucked and left in the setting.
- Marking low-value/non-merchantable wood (i.e., Z and Y Grades) for the purpose of leaving on site (mark to leave, MTL). A scaler marks low-value/non-merchantable wood with paint after falling and bucking, but prior to yarding.

In 1999, Weyerhaeuser's BC Coastal Group and the BC Ministry of Forests embarked on a co-operative project to examine the feasibility of applying the above modified practices, currently used in Weyerhaeuser's helicopter operations, to other harvesting systems. The perceived benefits included: i) reduced costs associated with yarding, loading, trucking, and disposing of low-value/non-merchantable, and ii) increased amount and distribution of coarse woody material retained in the cutblock.

Prior to embarking on the multi-year project proposed in the working plan[14], a decision was made to complete a pilot study in order to evaluate the sampling protocol and the operational feasibility of applying these modified practices to other harvesting systems. Opportunities to increase CWD retention by protecting existing dead wood on the ground, or by providing for leave trees, were not incorporated into the pilot.

In 1999 an old-growth stand with a high proportion of defective wood was chosen as the site for the pilot study. An old-growth rather than a second-growth site was chosen for study because the benefits of applying the modified bucking and yarding practices in younger stands were expected to be limited, due to the low volumes of defective wood in these stands.

The site selected for the pilot study was divided into two study blocks, one of which was harvested by conventional means and the other by a mark-to-leave method. Evaluation of the two methods was based on a comparison of costs and on an assessment of the pre- and post-harvest dead wood.

3.2 Study Objectives: Economic and Dead-Wood Components

3.2.1 Broad Objectives

The overall objectives of the pilot and main (multi-year) study have two basic components:

Economic component

- Monitor and compare the logistics of conventional yarding with yarding where low-value/non-merchantable wood (i.e., Y Grade and Z Grade) is marked.
- Estimate the costs of loading, transporting, and sorting low-value/non-merchantable logs (i.e., Y Grade and Z Grade).
- Determine whether the marking of low-value/non-merchantable wood (i.e., Y Grade and Z Grade) after falling put prior to yarding is an effective and economically feasible method to increase CWD left in post-harvest settings.

Dead-wood (CWD) component

- Provide baseline data about the structure of old-growth forests.
- Quantify pre- and post-harvest differences in CWD attributes between conventional and modified bucking and yarding practices.
- Compare potential pre-harvest sources of CWD and associated attributes to post-harvest CWD attributes.
- Quantify CWD volume and piece density removed through post-harvest salvage.

3.2.2 Objectives of the Pilot Study: Assess Pre-Harvest Dead Wood

The specific objectives of the pre-harvest survey of dead wood are to:

- Test for between-block differences in total site, live tree, dead tree, CWD, and stump volumes (H_0: no significant difference between Conventional and Mark-to-Leave Blocks);
- Test for between-block differences in merchantable and non-merchantable wood volumes (H_0: no significant difference between Conventional and Mark-to-Leave Blocks); and
- Test for between-block differences in the density and volume of "potential" large low-value/non-merchantable logs in the standing timber (H_0: no significant difference between Conventional and Mark-to-Leave Blocks).

[13] In the case of stands that were "high-graded" during previous harvesting operations, residual CWD levels may be higher than expected.

[14] G. Davis, E. Phillips, and B. Cawley. 2000. *Maintaining Coarse Woody Debris in Post-Harvest Settings: Economic and Ecological Implications of Marking Non-Merchantable Logs after Bucking and Before Yarding, Project Plan.* Research Section, Vancouver Forest Region, BC Ministry of Forests. VFR-CWD-00-01, internal document.

4 PROJECT DESIGN AND IMPLEMENTATION

4.1 Site Selection

Selection of the study site was governed to a great extent by harvesting schedules; the intent was to have harvesting completed by the end of the BCMOF's 2000/2001 fiscal year (i.e., March 31). General site and operational factors considered in the site selection include:

- Old-growth stand.
- "Uniformity" of timber types: <3 dominant types.
- "Uniformity" of dominant moisture/nutrient regime: <3 dominant regimes.
- Site size between 20 and 30 ha, to permit division into two study blocks.
- Travel distance <1.0 h from main junction.
- Presence of decay/waste/breakage indicators in stand.
- Ability to split block into two fairly homogeneous study blocks.

Old-growth was targeted because these forests/ecosystems have the greatest volume of low-value wood due to advanced stand age and a corresponding high level of defect and decay.

4.2 Site Description[15]

The harvesting site is located in Tree Farm Licence 39 of Weyerhaeuser's North Island Timberlands, Kelsey Bay Operations; Weyerhaeuser identifies the site as Block Number OP. 3057 UA106D3F. It is located on north Vancouver Island, in the Adam River drainage: 10 km north of the Sayward junction on Highway 19, 600 m left past the Keta Lake rest area and 8.5 km northwest up the Adams River branch road UA106D3.

The harvesting site is located in the Montane variant of the Very Wet Maritime subzone of the Coastal Western Hemlock biogeoclimatic zone (CWHvm2) and is classified as Natural Disturbance Type 1 (NDT1 = disturbance interval >250 years) (BCMOF 1995.) It is in a mid to upper slope position at an elevation of 740–940 m. The block is located on well drained gentle to steep slopes (25–60%); faults are associated with the latter. The slopes are east to north facing.

The soils are well drained, shallow to moderate, medium textured (silt loam mineral horizons) over compacted tills or bedrock outcrops. Coarse fragment contents vary from 40 to 60%. The soils are classified as Humo-Ferric Podzols. The overlying humus form is a MOR ranging from 15 to 30 cm deep.

The site is uniformly zonal (01) with small localized areas of moister, richer sites in the vicinity of seepage/stream locations. The three seepage areas identified are 07 and 10 site series. The moisture/nutrient regime for the majority of the block ranges from 3/C to 4/C.

The opening includes an in-stand reserve (0.5 ha) which is entirely within the opening boundaries and incorporates an area of steep rock outcrops and a long, narrow, natural, rock crevasse feature. A large Wildlife Tree Patch is adjacent to the site.

4.3 Stand Description

The forest is an uneven-aged, old-growth stand (150 to ≥450 years). It is comprised of western hemlock (Hw) (*Tsuga heterophylla*) and amabilis fir (Ba) (*Abies amabilis*), with a minor component of cypress (yellow-cedar) (Yc) (*Chamaecyparis nootkatensis*) **(Figure 1)**. As per the operational cruise, total net merchantable volume is estimated at 852 m^3/ha with a species composition of $Ba_{49}Hw_{48}Yc_3$ **(Table 3)**. The forest cover is semi-open, and multi-storied, with 25–30-m-tall Hw and Ba over intermediate BaHw layers including advance regeneration that is 2–10 m tall. Crown closure varies from 50 to 80%. The standing timber has a high occurrence of conks, dead or broken tops, and scars **(Figures 2, 3, and 4)**. Snag density is fairly low. The dead wood on the ground ranges from Moderately Decayed to Well Decayed **(Figure 5)**. It is assumed that this stand is representative of old-seral forests in the Montane variant of the Very Wet Maritime subzone of the Coastal Western Hemlock biogeoclimatic zone (CWHvm2) being harvested by the Kelsey Bay Division of Weyerhaeuser's Coastal BC Group.

Four broad timber types were identified **(Table 4)**. Their approximate locations are provided in **Figure 6**.

4.4 Layout

The harvesting site is 24.6 ha; this excludes an 8.6-ha Wildlife Tree Patch that lies outside the block boundaries, but includes a 0.5-ha in-stand reserve. Based on operational constraints, the

Figure 1. Site overview. (Photo: E. Phillips, FERIC)

[15] The information presented here about the site has been garnered from the following two documents:

–R.A. Harder and L.W. Apedaile, *Silviculture Prescription for BLK 3057*, November 27, 1998; Weyerhaeuser, BC Coastal Group, Nanaimo, BC; internal document.

– M. Fidgeon, *Coarse Woody Debris (CWD) Pilot Study – Field Assessment of Potential Study Sites, November 21, 2000*; Vancouver Forest Region, BC Ministry of Forests, Nanaimo, BC; internal document.

Table 3. Stand statistics: Operational Cruise Summary. [a]

Parameters/characteristics	Cypress		Western hemlock		Amabilis fir		Total	
Utilization limits								
Min. dbh (cm)	17.5		17.5		17.5		17.5	
Stump height (cm)	30.0		30.0		30.0		30.0	
Top diam. (cm)	15.0		15.0		15.0		15.0	
Log length (m)	n.a.		n.a.		n.a.		n.a.	
Net vol., by grade (m^3/ha/% net merch. vol.)					7.3	2%	7.3	1%
Grade D	3.8	14%	4.1	1%	6.1	1%	14	2%
Grade F	12.0	43%	59.2	14%	135.5	33%	206.7	24%
Grade H	2.5	9%	91.3	22%	55.3	14%	149.1	17%
Grade I			26.6	6%	49.1	12%	75.7	9%
Grade J	7.6	27%	149.8	36%	103.0	25%	260.6	31%
Grade U	1.4	5%	22.5	5%	11.3	3%	35.2	4%
Grade X	.9	3%	63.4	15%	39.3	10%	103.5	12%
Grade Y	28.1	101%	416.9	99%	407.1	100%	852.1	100%
Total net (m^3/ha)	3.3		48.9		47.8		100	
Species % of total net blowdown (%)								
Cull (waste), Grade Z (m^3/ha)	0.0		2.6		0.8		3.4	
Breakage (m^3/ha)	2.1		29.4		27.0		58.5	
Decay (m^3)	1.9		89.8		44.8		136.5	
Total deduction (m^3/ha)	4.0		121.8		72.6		198.4	
Total gross merch. vol. (Tree Class A+B+C) (m^3/ha)	32.1		538.7		479.7		1050.5	
Cull % of gross merch. vol. (Tree Class A+B+C) (%)	12.5		22.6		15.1		18.9	
APS, avg. top diam. inside bark, by grade (m^3/cm)								
Grade D					5.65	94	5.65	94
Grade F	3.96	68	2.91	62	2.89	74	3.13	69
Grade H	3.07	52	2.77	58	2.00	51	2.22	53
Grade I	2.01	49	3.07	64	2.41	60	2.77	62
Grade J			0.57	24	0.56	26	0.56	25
Grade U	1.02	25	1.16	30	0.61	22	0.85	26
Grade X	4.90	136	0.91	37	1.35	49	1.06	41
Grade Y	1.40	109	0.85	38	0.63	32	0.75	35
Species APS, top diam. inside bark	1.95	43	1.27	37	0.96	32	1.11	34
Stems/ha, by dbh range								
17.5-22.4 cm (no.)			18.6		24.4		43.0	16.2%
22.5-32.4 cm (no.)					24.0		24.0	9.0%
32.5-47.4 cm (no.)			26.8		30.5		57.3	21.5%
47.5-72.4 cm (no.)			29.1		42.7		71.8	27.0%
72.5-97.4 cm (no.)	3.9		21.5		19.2		44.6	16.8%
97.5-195 cm (no.)	0.3		18.8		6.3		25.4	9.6%
195.1+ cm (no.)								
Total	4.2		114.8		147.1		266.1	100%
Stems/ha, by tree class								
Class A, live standing (no.)	4.2		112.6		145.3		262.1	98.2%
Class B, dead standing (no.)			2.2		1.8		3.9	1.5%
Class C, dead down (no.)								
Classes D & F combined, useless (no.)			5.8		8.9		14.7	
Avg. merch. height (m)	29.0		22.8		20.9		21.8	
Avg. total height (m)	33.9		29.3		27.2		28.2	
Poles and pilings								

[a] Source: Weyerhaeuser cruise data (26 samples, Cruise Project No. 8614).

harvesting site was split into two study blocks with the access road serving as the most efficient dividing line. The conventional and mark-to-leave practices were randomly assigned to the study blocks. Two yarding methods were used in both blocks: excavator (hoe) forwarding to roadside and grapple yarding (Phillips 2001). In this report the two study blocks are referred to as the Mark-to-Leave Block and the Conventional Block.

Table 5 summarizes the area associated with each study block, treatment, and harvesting method. Figure 6 shows block layout.

4.5 Bucking and Yarding Practices

The following provides a brief overview of the operational aspects of the two practices evaluated in the study. Further detail is available in a progress report produced by the Forest Engineering Research Institute of Canada (FERIC) (Phillips 2000) and in Appendix B. **Table 6** provides an approximate schedule of activities.

As a general rule, each harvesting stage was completed in the Conventional Block prior to the Mark-to-Leave Block. The presence of fog and snow started to affect the yarding by mid October. This was early on in the yarding phase of the Mark-to-Leave Block. November 24, 2000 was the final day for

Figure 2. Conks. (Photo: C. Redlin, Azmeth Forest Consultants)

Figure 3. Frost crack. (Photo: C. Redlin, Azmeth Forest Consultants)

Figure 4. Windfall. (Photo: C. Redlin, Azmeth Forest Consultants)

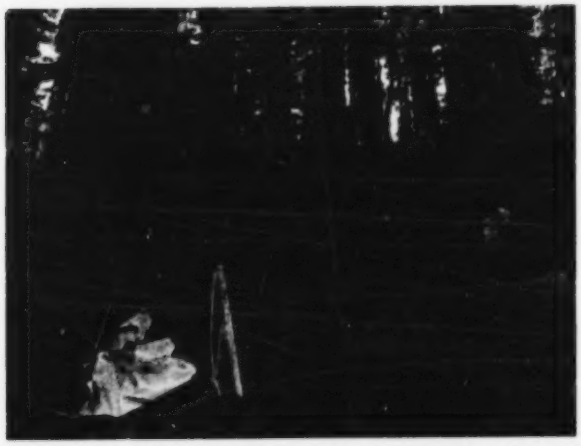


Figure 5. Well-Decayed CWD. (Photo C. Redlin, Azmeth Forest Consultants)

Table 4. Broad timber types found at the study site.

Timber type	Species	Total area (ha)
1	BaHw (large-diameter BaHw)	9.7
2	BaHw (large-diameter Ba and small-diameter Hw)	2.6
3	BaHw (small-diameter Ba and small-diameter Hw)	4.95
4	BaHw (small-diameter Ba and large-diameter Hw)	6.05

operations. At shut down, less than 20% of the volume on the Mark-to-Leave Block remained to be yarded. Over 50% of the mark-to-leave wood was cold decked for hauling in the spring. During operations, the crew worked around weather-related shutdowns (e.g., a record rainfall on October 20, fog, snow); scheduled operational shutdowns (October); scheduling of equipment; staff holidays; and staff changes.

4.5.1 Falling, Bucking, and Marking

Separate falling crews were used in each block. Hand falling was used on both blocks (Phillips 2001). The modified bucking/yarding was carried out by a crew that had prior experience with "best value" bucking in Weyerhaeuser's helicopter operations.

Conventional Block. Trees were felled and bucked to Weyerhaeuser's preferred log lengths, which are based on grades (Appendix B-2 of Appendix B). Four fallers were involved in the conventional harvesting.

Table 5. Areas corresponding to site, Wildlife Tree Patch, and yarding method, by study block.

Parameters	Area	Study block: Mark-to-Leave	Study block: Conventional
Site and Wildlife Tree Patch sizes			
Gross area of harvesting site (ha)	33.0		
Area of Wildlife Tree Patch outside the boundaries of the harvesting site (ha)	8.6		
Gross harvesting area, including Wildlife Tree Patch within harvesting boundaries (ha)	24.6		
Area of Wildlife Tree Patch within harvesting boundaries (ha)	0.5		
Road occupancy (ha)	0.8		
Total net (ha)	23.3		
Yarding method			
Roadside area (ha)		1.5	2.7
Hoe-chucked area (ha)		1.2	0.6
Grapple yarded area (ha)		7.0	10.3
Total area designated as dispersed (ha)		8.3	10.9
Total roadside + dispersed (ha)		9.7	13.6
Total net (%)		42	58
Distribution of plots			
Total plots designated as dispersed (no.)		11	12
Total dispersed area (%)		13	11

Table 6. General schedule of activities.

Activity and study block	Start/end date
Falling/bucking	
Conventional	19 July 2000 start
Falling	
Mark-to-Leave	24 July to 18 September 2000
Hoe forwarding	
Conventional	07 September 2000 start
Mark-to-Leave	02 October 2000 complete
Cable yarding	
Conventional	12 September to 10 November 2000
Mark-to-Leave	13 November to 24 November 2000 (02 May to 18 June 2001)
Scheduled shutdown	06 October to 16 October 2000
First snow	11 November 2000

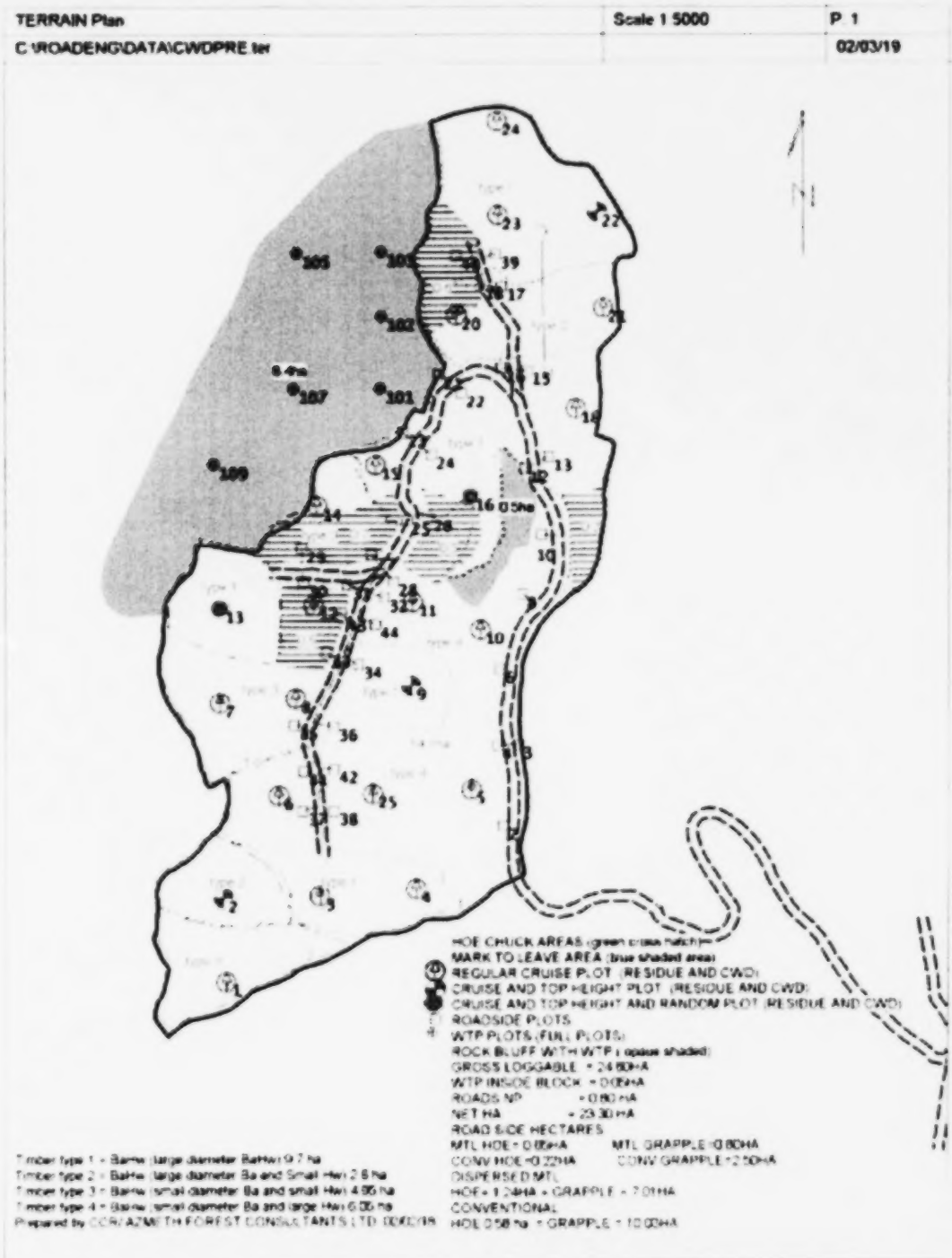

TERRAIN Plan
Scale 1 5000
P 1
C:\ROADENG\DATA\CWDPRE.ter
02/03/19
HOE CHUCK AREAS
MARK TO LEAVE AREA (blue shaded area)
REGULAR CRUISE PLOT (RESIDUE AND CWD)
CRUISE AND TOP HEIGHT PLOT (RESIDUE AND CWD)
CRUISE AND TOP HEIGHT AND RANDOM PLOT (RESIDUE AND CWD)
ROADSIDE PLOTS
WTP PLOTS (FULL PLOTS)
ROCK BLUFF WITH WTP (opaque shaded)
GROSS LOGGABLE = 24.6 0HA
WTP INSIDE BLOCK = 0.0 0HA
ROADS NP = 0.80 HA
NET HA = 23.30 HA
ROAD SIDE HECTARES
MTL HOE = 0.0 0HA
MTL GRAPPLE = 0.0 0HA
CONV HOE = 0.22HA
CONV GRAPPLE = 2.50HA
DISPERSED MTL
HOE = 1.24HA + GRAPPLE = 7.01HA
CONVENTIONAL
HOE 0.58 ha + GRAPPLE = 10.00HA
Timber type 1 = Bafhw large diameter Ba/Hw1 9.7 ha
Timber type 2 = Bafhw large diameter Ba and Small Hw1 2.8 ha
Timber type 3 = Bafhw small diameter Ba and small Hw1 4.95 ha
Timber type 4 = Bafhw small diameter Ba and large Hw1 6.05 ha
Prepared by CORI AZMETH FOREST CONSULTANTS LTD 00/07/18

Figure 6. Site map (scale 1:5000). (Map prepared by C. Redlin, Azmeth Forest Consultants, 00/7/18)

Mark-to-Leave Block. After falling, licensed metric log scalers trained a second four-person falling crew to buck to recover maximum log value and to decrease the amount of cull attached to market logs, without increasing the volumes of billable residue and waste.

The second falling crew was given detailed bucking instructions for the Mark-to-Leave Block, with specific reference to: retaining long butts where there was a severe defect or rot; bucking out log sections with conks; removing shattered portions of logs; bucking out portions of the tree containing Y or Z Grade wood; and maximizing the value of logs bucked from each tree by ensuring diameter, length, and quality of log were optimized. Further detail is provided in Appendix B.

Following bucking, but prior to yarding, licensed metric log scalers (who are also residue and waste surveyors) marked with paint any log that had been bucked off to minimize cull i.e., low-value wood or because it was below minimum recovery specifications. Several blue spots, each approximately 20 cm^2, were painted on the log on the side that would be visible to the yarder. Mid way through yarding, pieces were remarked with a more-visible pink paint because the snow had obscured or faded the original marks.

4.5.2 Yarding Practices

There was considerable overlap in yarding operators and equipment used in both blocks. The majority of the harvesting site was grapple yarded by a three-drum Madill 044 swing-yarder equipped with a single walking guy line. Gentle terrain was excavator forwarded (hoe-chucked) with a Kobelco SK400LL hydraulic log loader. This machine was also used for wide right-of-way yarding and for loading trucks. Wood was yarded both uphill and downhill in the Conventional Block and downhill in the Mark-to-Leave Block. Logs were transported with tridem/tridem-tractor/pole-trailer highway trucks (7-axle configuration) to a central dryland log-sorting yard via off-highway roads (Phillips 2001).

Conventional Block

Excavator Forwarding. The excavator-operator commented that, as a general rule, he was able to identify low-value/non-merchantable wood, because he was able to move each piece and bring it close to the cab. For various reasons low-value/non-merchantable pieces were often displaced from their original locations. In some cases, wood was forwarded with one or more swings before determining that it was in fact low-value/non-merchantable. In other cases it was necessary to move logs to provide access or machine corridors, or to improve visibility for determining merchantability. Small and/or broken pieces were piled by the excavator to improve its mobility and to improve access to wood.

Grapple (Cable) Yarding. The yarding engineer determined merchantability, with the assistance of spotting by the hooktender when the logs were not clearly visible. When the yarding was complete on one yarding road, the hooktender walked the yarding road to ensure all merchantable wood had been yarded before the yarder or backspar were moved to access a new, unyarded area. If the yarding engineer questioned the merchantability of a log, then the hooktender (spotter) was asked to do a close-up visual inspection of the log. The yarding engineer dropped any log that started to fall apart during grappling or hauling, and went back for another.[16] The yarding engineer and the hooktender communicated by radio.

Mark-to-Leave Block

The yarding and loading operators were informed that, if possible, they were not to yard or load any marked logs. They were also asked to watch for, and leave on site, any obvious cull logs that were not painted. A quality-control supervisor, who visited the yarding and loading crews approximately every two weeks, monitored the operations.

Excavator Forwarding. The excavator-operator was able to see the blue paint with minimal trouble. Nevertheless, sometimes pieces of wood had to be moved, sometimes more than once, in order to check for paint, to ensure no merchantable wood was underneath the piece, and to provide access for the hoe. As a result, pieces were often not left in their original locations.

Grapple (Cable) Yarding. In the Mark-to-Leave Block, grapple yarding occurred in much the same fashion as in the Conventional Block, with the exception that pieces marked with blue paint were to remain in the setting. The hooktender and the chaser (when available) also assisted with identifying painted logs where visibility was poor (e.g., due to snow, gullies, knobs).

The yarding engineer commented that, where the terrain was steep, marked pieces were often inadvertently moved from their original locations, for several reasons. Typically a piece was picked up by the grapple for the operator to view. If paint was obviously visible the piece was dropped; however, in sloping terrain the piece would often roll into an unyardable area, e.g., a gully or out of reach of the yarder. If the paint was not obviously visible the piece was yarded toward the road until the paint became visible, at which time the piece was dropped. In these two scenarios, accumulations can occur in specific locations along the slope. In other instances, the grapple may have picked up two pieces, one with and one without paint. Both were yarded to the roadside, one was hauled, and the other was left at the roadside. Fog and snow compounded these problems.

5 METHODS

5.1 Definitions

Trees: Live and dead trees that are ≥3 m in height with a dbh ≥10 cm; fallen trees must have roots attached and dbh within the

[16] Eric Phillips, Senior Researcher, Silviculture Group, Western Division, Forest Engineering Research Institute of Canada (FERIC), Vancouver, BC; personal communication, June 2001.

cruise plot boundary (see Cruise Measurements section below).

Stumps: Natural or cut tree, with roots attached and rooted, ≥0.3–2.99 m in height with a top diameter ≥10 cm.

CWD: Natural or cut, dead, down wood with a small-end diameter ≥10 cm; overlap with windfalls was recorded.

5.2 Cruise Measurements

The cruise procedures follow the *Vegetation Resources Inventory Ground Sampling Procedures Manual* (BCMOF 2000c), with the exception that nested fixed-area plots rather than variable radius (prism) plots were used and Z Grade logs were distinguished from Y Grade logs. A total of 23 sample plots were located systematically throughout the cutblock: 12 in the Conventional Block and 11 in the Mark-to-Leave Block. These 23 plots were located in the area outlined on the harvesting map as the dispersed stratum. Each cruise plot consisted of two nested sub-plots with radii equal to 11.28 m and 17.84 m **(Table 7)**. The 11.28-m radius subplot (400 m^2) included measures on all standing and fallen trees ≥10 cm dbh, while the 17.84-m subplot (1000 m^2) includes measures on all trees ≥50 cm dbh. Plot centers were staked, pinned, and referenced to at least two trees within the plot.

For all trees, standing or fallen (1.3 m in plot with roots), the following attributes were recorded: species, dbh, actual height, live/dead, standing/fallen, crown class, height to live crown, net factor call grading for all logs, pathological indicators, Wildlife Tree appearance codes, and tree class codes. **Table 8** provides general definitions for tree classes used in the study. Further information on measurement attributes is available in the Working Plan[17]. Trees along the boundary of any plot[18] were included in the tally if 50% or more of the tree at dbh was inside the plot boundary.

5.3 Measurements of Coarse Woody Debris and Stumps

Measurement of CWD and stumps followed field procedures outlined in the *Logging Residue and Waste Procedures Manual* (BCMOF 2000a) with two major modifications:

i) nested, fixed-area plots were used, and

ii) low-value/non-merchantable wood was measured.

Three, rather than two, fixed-area nested sub-plots were used to measure down wood at the same locations as the pre-harvest cruise plots (see Section 4.2 of this report) The three sub-plot radii were 3.99 m (50 m^2), 11.28 m (400 m^2)[19], and 17.84 m (1000 m^2). The two largest diameter sub-plots coincide with the nested cruise plots. The piece-selection criteria for each plot follows:

- 3.99-m plot: pieces and/or stumps in the plot with a volume <0.024 m^3 (entire piece) and a small-end inside bark diameter ≥10 cm.
- 11.28-m plot: pieces and/or stumps in the plot with a volume ≥0.024 m^3 and a small-end inside bark diameter ≥10.
- 17.84-m plot: pieces and/or stumps in the plot with a volume ≥0.024 m^3 and a small-end inside bark diameter ≥30 cm.

Attributes both inside and outside each plot (e.g., length, small-end and large-end diameters) were recorded. For all plots, the minimum small-end inside-bark diameter was 10 cm, and length was recorded to this minimum. The purpose of the nested plots and minimum size criteria were to increase the sampling rigour for large pieces. A CWD piece 3 m in length with a minimum 10-cm small-end diameter fits the *Manual's* definition of a residue and waste log (for second growth).[20]

Plot boundaries were painted on the ground prior to field sampling. Field measurements included: species; borderline (i.e., whether or not the piece intersects the plot boundary); kind; waste class; small-end and large-end diameters inside and outside the plot; large-end and small-end codes; piece length inside and outside the plot; grades and deductions for the sections of log within and outside the plot; codes for live, dead, or original; and comments (e.g., number of segments, buried, reconstructed). Additional measurements included ecological codes (decay, bark, hardness, and orientation). Appendix V of this project's working plan[21] provides more detail.

General sampling rules included:

- Record width and height (inside bark) for all pieces with non-round diameters (all pieces with a decay code of 3, 4, or 5).
- Measure broken pieces <0.5 m apart as if they were one piece (if they are positioned in the same direction and it is clear they originate from the same log) and record number of segments.
- Reconstruct pieces that are split horizontally but still have a portion touching each other.
- Assess grade and % sound separately for the log portions inside and outside the plot, and assess ecological decay codes, % bark, and hardness for the entire piece.

Table 7. Summary of pre-harvest strata.

Stratum and plot type	Radii of nested plots: Pre-harvest (m)
Cutblock [a]	
Cruise	11.28/17.84
Stump/CWD	3.99/11.28/17.84

[a] Referred to as dispersed post-harvest.

[17] See Footnote 14.
[18] A tree was included in the timber cruise if it had attached roots and its dbh (1.3 m from high side) was within the plot boundary.
[19] An 11.28-m radius plot is the standard residue and waste plot size. The larger plot (17.84 m) will improve parameter estimates for larger sized pieces. In future two plot sizes rather than three will be used, to make data collection easier.
[20] A CWD piece with large-end and small-end diameters of 10 cm and 3 m long is equal to 0.024 m^3 (assumes minimum taper).
[21] See Footnote 14.

Table 8. Definitions of tree classes used by Weyerhaeuser and the BCMOF.

Weyerhaeuser's Tree Classes	BCMOF's Corresponding Tree Classes (BCMOF 2000b)
A - Live Stem Live, standing trees.	1 - Living trees with none of the eight external pathological indicators (Residual). 2 - Living trees with one or more of eight pathological indicators of decay: conks, blind conks, scars, fork and/or pronounced crook, frost crack, mistletoe (truck infection), rotten branches, dead or broken top (Suspect). 5 - A veteran is defined as a mature living tree (121 years or older for all species except deciduous >40 years or cottonwood and aspen in FIZ K&La >80 years) in a main stand which has been classified as immature (<121 years) (Veteran). 6 - Living trees that have only one or two live limbs. They are combined with Tree Class 4 for the compilation of % snags. 8 - An immature stem is defined as an immature tree (<121 years) within a mature stand.
B - Dead Potential Standing Dead, standing trees with at least 50% of its original gross volume in sound-wood content.	3 - Dead standing or down timber which is estimated to contain at least 50% of its original gross volume in sound-wood content (Dead Potential). 7 - This class combines the definition of Tree Classes 5 and 3 and is referred to as a Vet-eran Dead Potential. The loss factor tables for combined Tree Classes 5 and 3 are applied in the compilation. 9 - This class is combines the definition of Tree Classes 8 and 3 and is referred to as Im-mature Dead Potential. The combined Tree Class 8 and 3 loss factors are applied in the compilation.
C - Dead Potential Fallen Dead, fallen trees with at least 50% of its original gross volume in sound-wood content.	3 - As above. 6 - As above. 7 - As above. 9 - As above.
D - Dead Useless Standing Dead standing trees that have <50% of their original gross volume in firm-wood content or otherwise fail to meet the criteria of the above Dead Potential Standing definition.	4 - Dead standing trees that have <50% of their original gross volume in firm-wood content or otherwise fail to meet the criteria of Tree Class 3 (Dead Useless).
E - Dead Useless Fallen Dead fallen trees that have <50% of their original gross volume in firm-wood content or otherwise fail to meet the criteria of the above Dead Potential Fallen definition.	

[a] FIZ K&L = Forestry Inventory Zone. (K = North Central Region, Cassier, Omineca. L = North Eastern plains.) (BCMOF 2000b).

• Record the outside and inside dimensions of hollow logs (i.e., small-end and large-end diameters).

• Record two types of windfalls (i.e., logs with roots attached)—those with the 0.3-m bole inside the plot and those with the 0.3-m bole outside the plot.

5.4 Site Index and Tree Age

Prior to the commencement of harvesting, 5 of the 23 cruise plots were randomly selected for site-index (SI) measurements. A 0.01-m^2 plot was established in the center of each cruise plot and one site index (SI) tree of the leading species and one of the secondary species were selected from each plot (see Section 4.8 of *Vegetation Resource Inventory Manual* (BCMOF 2000c).

On three of the five plots, two dominant or co-dominant trees of the leading and secondary species, in addition to two intermediate trees of the leading species, were randomly selected for determining tree age. Trees were selected irrespective of defects.

Both SI and random trees were triangulated to the plot center. Stem maps were drawn to permit post-harvest collection of disks.

6 ANALYSES

The overall objective of the pilot study analysis is to estimate and compare relevant properties of the Conventional and Mark-to-Leave Blocks, before and after harvesting. This information will be used to assess the merits and potential difficulties of conducting the multi-year study in which the two harvesting methods will be replicated at other sites. The pre-harvest analyses include only the 23 plots located in the area identified as the dispersed stratum, i.e., the analyses exclude roadside.

6.1 Pre-Harvest Analyses

The specific objectives of analysing the pre-harvest data are to:

1. Describe the pre-harvest conditions in the Conventional and Mark-to-Leave Blocks, by estimating (for each block) the parameters listed in **Tables 9 and 10**.

2. Test whether the total volumes and total dead-wood volumes and component volumes (e.g., Z and Y Grades) differed significantly between the two blocks before harvest-

Table 9. Compilation piece definitions. [a]

1 - Live and dead standing and fallen trees (≥3 m in height) *Cruise trees:* standing and fallen trees (i.e., windfallen [b]) with a dbh ≥17.5 cm. *Undersized Trees:* standing and fallen trees with a dbh ≥10 cm and <17.5 cm.	i) **Density** (number trees/ha, cruise and undersized). ii) **Gross volume/ha** *Cruise trees* - 1) merchantable-sized logs to a 15-cm inside bark top diameter; 2) top (bole from 15-cm inside bark diameter to tree top) and stump (<0.3 m in height) combined. *Undersized trees* - 1) no merchantable-sized logs because dbh <17.5 cm; 2) tops, entire tree to a 0.3-m stump height; 3) stumps, <0.3 m in height. iii) **Net volume/ha** Cruise trees - merchantable-sized logs to a 15-cm inside bark top diameter. Undersized trees - no merchantable net volume.
2 - Stumps (rooted dead wood with a dbh or top diameter ≥10 cm, which is ≥0.3m and <3.0 m in height)	i) **Density** (number of stumps/ha). ii) **Gross volume/ha** Gross volume/ha of paraboloid (Smalian formula) ≥0.3 m in height (stump volume <0.3 m in height is not calculated or tracked).
3 - CWD (all dead down pieces) *Windfalls:* portions of windfalls within fixed-area plot between the large-end IB diameter and a minimum small-end IB diameter ≥10 cm. *Other CWD (non-windfalls):* portions of all other dead down and non-supporting wood within the fixed-area plot between large-end inside bark diameter and minimum small-end inside bark diameter ≥10 cm	i) **Density** (number of pieces/ha). Sum of windfall and "other" CWD pieces. ii) **Gross volume/ha** (sum of windfall and "other" CWD gross volume to a small-end IB diameter of 10-cm). *Windfalls* - gross volume/ha of section of tree bole within the fixed-area plot from the butt to a small-end IB diameter of ≥10 cm. No volume is calculated for the root wad. *Other CWD* - gross volume/ha piece within the fixed-area plot based on Smalian equation to a small-end IB diameter of 10-cm. iii) **Net volume/ha** Sum of windfall and other CWD net volume within the fixed-area plot based on residue and waste deductions.

[a] All taper equations based on Kozak 1988. [b] Windfalls have roots attached.

Table 10. List of attributes used to compare the study blocks prior to harvesting, and corresponding units of measure. [a]

Attribute	Units of measure	
Total site gross volume and piece density (live + dead)	m^3/ha	no. pieces/ha
Strata total gross volumes and piece densities, i.e., live, dead standing, CWD, stumps, total dead	m^3/ha	no. pieces/ha
Total cruise gross and net volumes, by tree class and log grade	m^3/ha	
Total cruise value, by tree class and log grade	$/ha	
Total site gross volume, by log grade (i.e., Y, Z, X+U, X and better)	m^3/ha	
CWD volume and density: diameter, by length classes	m^3/ha	no. pieces/ha
CWD volume and density: diameter, by decay classes	m^3/ha	no. pieces/ha
Large CWD pieces (upper 10% for length and diameter)	m^3/ha	no. pieces/ha
Potential total low-value/non-merchantable logs in cruise trees, by diameter and length classes	m^3/ha	no. pieces/ha
Potential large low-value/non-merchantable logs in cruise trees (upper 10% for length and diameter)	m^3/ha	no. pieces/ha

[a] The cruise definition of dead wood includes dead standing trees and windfalls. The definition of CWD includes all down wood, including portions of windfalls in the fixed-area plot. Other CWD is CWD excluding windfalls measured in the cruise. Table 11 demonstrates the difference between windfall volume calculated using the taper equation (entire tree) and the Smalian equation (portion of windfall within the fixed-area plot).

Table 11. Comparison of total gross volume/ha of windfalls for Tree Class C: cruise taper equation versus Smalian equation of piece within plot.

Tree Class	Entire tree (taper equation)	Portion of piece within plot (Smalian equation)
C	12.7±5.2	9.8 ± 3.5

ing occurred. Estimating and testing the statistical significance of pre-harvest differences, although not definitive, provide insight into the interpretation of post-treatment results and possible impacts on CWD of a mark-to-leave strategy (e.g., if the pre-harvest differences were negligible then the magnitude and sign of any post-harvest differences might be more or less predictive of yarding effects at similar sites in the same subzone variant and age class). However, owing to a lack of replication of the conventional and mark-to-leave methods at more than one site, analysis of the post-harvesting differences between the two blocks cannot distinguish conclusively between a yarding effect and natural variability over space or time (i.e., post-harvest differences may simply reflect natural variability among blocks that was not initially evident).

6.1.1 Statistical Methods

In order to classify the CWD pieces by size (diameter and length), empirical cumulative distribution functions (CDF), $\hat{F}(x)$, were calculated based on the diameters and lengths of the pre-harvest CWD pieces. The cumulative distribution frequency provides an estimate of the proportion of CWD pieces (per hectare) that have diameters (or lengths) less than or equal to an arbitrary diameter (length) x. Estimates of the diameters (lengths) that correspond to the upper 20, 10, 5, 2, and 1% of the diameter (or length) distribution were determined by (numerically) inverting $\hat{F}(x)$. Pieces with diameters (lengths) corresponding to the upper 10% were classified as "large".

Volumes of individual trees and pieces of CWD were calculated using standard cruise (Kozak 1988) or residue and waste formulas (e.g., frustrum of a paraboloid), totalled for each sample plot (for each grade and for all grades combined), and divided by the plot area to obtain an estimate of (tree or CWD) volume per unit area (m^3/ha).[22] The density of CWD pieces (number of pieces/ha) was calculated in the same manner (i.e., total number of pieces in plot/plot area). If a piece of CWD extended beyond the plot boundary then only that portion contained in the plot was included (e.g., if 45% of the volume lay within the plot then 0.45 x volume was included in the volume total, and a count of 0.45 was added to the total number of pieces). Plot

[22] For each piece, total volume is based on the sum of the individual log volumes rather than the total piece volume. Individual tree and log volumes were compiled by Olympic Resource Management, 300–475 W. Georgia, Vancouver, BC.

totals were obtained for each attribute of interest (Table 9). Zeroes (0 m^3/ha or 0 pieces/ha) were recorded for all plots that did not contain trees or CWD with the applicable attributes.

Basic statistics—sample mean, standard deviation (standard error of the sample mean, SE), minimum, maximum, coefficient of variation (CV), and sample size (number of plots)—were compiled for all attributes of interest and summarized for the two harvesting methods.

6.1.2 Tests of Hypotheses

Univariate (i.e., each attribute of interest was tested separately), two-sided t-tests were used to compare the attributes of the Conventional and Mark-to-Leave Blocks before harvest.

7 RESULTS

7.1 Selection of CWD Diameter and Length Classes

Tables 12 and 13 present large-end diameter (maximum dimension) and length percentiles, which are based on the respective empirical cumulative distribution frequencies for CWD in individual and combined blocks. The selected diameter and length classes **(Table 14)** represent a balance between diameter classes used in the studies reported in the literature and the site-specific cumulative distributions. The classes allow for comparisons with the data in the literature while providing a clear definition for large CWD pieces.

The diameter classes most commonly applied in the Pacific Northwest are listed in **Table 15**. For discussion purposes, Table 15 also presents the corresponding site-specific cumulative distribution frequency diameter breaks. It is, however, acknowledged that the two sets of diameter percentiles are not directly comparable because the former refer to an "average" diameter (e.g., diameter measured at the point of intersection with a line transect), while the latter are based on the large-end inside-bark diameter, which (by definition) exceeds the mean, except in those rare cases where all pieces of CWD are cylindrical.

In this study, the 90th percentile of the cumulative distribution frequency defines the largest diameter class. This is consistent with the principal underlying the *Biodiversity Guidebook* (1995) that when managing Wildlife Trees "care should be taken to include the upper 10% of the diameter distribution of the stand (taken from cruise data)..." (p. 64). The 70th percentile of the diameter cumulative distribution frequency represents the break for medium-sized CWD pieces, as it is mid way between the 50th and 90th percentiles. The 50th percentile of the diameter cumulative distribution frequency is the break for the small-sized CWD pieces. This diameter class corresponds

Table 12. Cumulative distribution frequencies for CWD length. [a]

Study Block	Percentile																	
	20th (m)	25th (m)	30th (m)	35th (m)	40th (m)	45th (m)	50th (m)	55th (m)	60th (m)	65th (m)	70th (m)	75th (m)	80th (m)	85th (m)	90th (m)	95th (m)	98th (m)	99th (m)
Both	0.6	0.7	0.8	1.1	1.2	1.4	1.6	2.0	2.3	2.6	**3.1**	4.0	4.9	6.7	**9.7**	**14.4**	22.6	26.1
Mark-to-Leave	0.7	0.9	1.0	1.1	1.4	1.5	1.9	2.2	2.6	3.0	**3.7**	4.5	6.2	8.2	**11.8**	**20.9**	25.4	28.4
Conventional	0.6	0.7	0.7	0.9	1.1	1.2	1.6	1.8	2.2	2.4	**2.7**	3.4	4.4	6.0	**8.1**	**11.6**	18.1	21.8

[a] Boldface numbers refer to the length and diameters used to define the diameter and length classes discussed in this report.

Table 13. Cumulative distribution frequencies for CWD, large-end diameter (inside bark). [a]

Study Block	Percentile																	
	20th (m)	25th (m)	30th (m)	35th (m)	40th (m)	45th (m)	50th (m)	55th (m)	60th (m)	65th (m)	70th (m)	75th (m)	80th (m)	85th (m)	90th (m)	95th (m)	98th (m)	99th (m)
Both	12.6	13.6	14.5	15.6	17.0	18.4	19.6	21.1	23.9	25.4	**31.9**	35.5	42.7	52.1	**62.9**	**77.4**	96.4	109.1
Mark-to-Leave	12.2	12.9	13.6	14.3	15.1	16.0	17.7	19.4	21.2	24.9	**32.3**	35.2	46.0	56.5	**66.6**	**80.2**	101.3	109.9
Conventional	13.2	14.5	15.8	17.4	18.5	19.4	20.6	22.5	24.5	25.6	**30.7**	35.8	39.8	48.9	**59.6**	**73.1**	91.4	105.0

[a] Data reported in this document are in boldface type.

Table 14. Diameter and length classes for specific cumulative percentiles.

Parameter	Percentile, and CWD class ≤70, Small	70-90, Medium	>90, Large	>95, Very Large
Large-end diameter (cm)	≤30	30-65	>65	>75
Piece length (cm)	≤3.0	3.1-10	>10	>14

Table 15. Examples of diameter classes used in the literature, and the corresponding cumulative diameter distribution percentages based on study results.

Source	Diameter class (cm)	Corresponding CDF in study (%)
Stone et al. 1998 [a]	21-40	52-79
	41-80	79-96
	>80	>96
Wells & Trofymow	15-30	32-69
	30-60	69-89
	>60	>89
Huggard 2000 [b]	12.5-30	17-69
	30-50	69-84
	50-80	84-96
	>80	>96
Goodburn & Lorimer 1998	<20	52
	20-40	52-79
	40-60	79-89
	>60	89
Spies et al. 1998 [a]	<30	<69
	30-60	69-89
	>60	>89

[a] Large-end diameter. [b] Transect diameter.

to the smallest diameter class discussed in the literature. CWD length is rarely reported in the literature. For consistency, the length cumulative distribution frequency breaks coincide with those used to define the diameter classes.

7.2 Site Overview

Tables 16 and **17**, respectively, summarize the estimated total number of pieces/ha and volume/ha partitioned by stratum: live trees, dead trees, stumps, CWD, and total dead wood, together with their associated standard errors. The total dead wood is the sum of the dead trees, stumps, and CWD. Tables 16 and 17 also presents the two-sided *p-value* ("*Prob.*") for assessing the statistical significance of the difference between the block means. The *p-value* is the probability that the magnitude of the difference between the block sample means would be as large as the observed value, assuming no difference between the population means. The null hypothesis is rejected when the *p-value* is ≤0.10, which is equivalent to applying a two-sided t-test with significance level $\alpha = 0.10$. The standard error of the difference between the two means gives an indication of the precision of the estimate or the size of the Type II error (i.e., the probability that the null hypothesis will not be rejected when it is false). Large standard errors imply that the t-test lacks power and that only the very large differences will be found to be statistically significant.

7.2.1 Number of Pieces/ha

The total number of pieces/ha is, on average, slightly lower in the Mark-to-Leave Block stratum than they are in the Conventional Block stratum. The two study blocks did not differ significantly with respect to number of pieces/ha for any stratum. However, owing to the high variability, as indicated by the large standard error associated with the differences (Table 18), the absence of statistically significant differences is suggestive rather than conclusive evidence that the study blocks were similar prior to harvest.

Over the entire harvesting site, the live trees and CWD represent the bulk (33% and 55%, respectively) of the total number of pieces. The combined total dead wood represents 67% of the total number of pieces/ha on the site, with CWD representing the bulk (77%) of the total dead-wood pieces.

7.2.2 Volume/ha

Volumes/ha in the Conventional Block strata are generally lower than the Mark-to-Leave Block means (Table 18). Total volumes/ha for the individual blocks were not significantly different for the following strata: live standing trees, dead standing trees, total dead, and total (all strata combined). The stump and CWD volume/ha were, however, significantly different ($p < 0.1$) between the two study blocks. In the case of CWD, this difference is indicative of differences in the piece-size distributions for the two study blocks (see Section 7.5.1 in this report). There was high within-block variability for all strata. This finding is not unexpected because natural regeneration and mortality often result in a clumpy distribution of trees and CWD. While total dead-wood volume was not significantly different between blocks, there was high variability within blocks and therefore the estimated difference has a large standard error.

Over the entire harvesting site, the live trees represent the bulk of the stand volume, or 70% of the total gross volume/ha. On a volume/ha basis, the total dead wood represents 26% (346 m^3/ha) of the total gross volume/ha, and CWD represents 67% (216 m^3/ha) of the total gross volume/ha of dead wood. The ratio of live to dead-wood volume/ha is 1:0.34.

Table 16. Total site density, by stratum (mean ± SE). [a]

Study block	Plots (no.)	Stratum: Live standing trees [a] (no. pieces/ha)	Dead standing trees [a] (no. pieces/ha)	Stumps [b] (no. pieces/ha)	CWD [c] (no. pieces/ha)	Total dead [d] (no. pieces/ha)	Total (no. pieces/ha)
Both	23	431.3 ± 36.0	60.2 ± 5.8	135.7 ± 26.8	670.0 ± 70.1	865.9 ± 80.2	1297.2 ± 97.3
Mark-to-Leave	11	385.0 ± 42.4	68.6 ± 7.6	116.4 ± 24.7	606.0 ± 96.0	791.0 ± 99.7	1176.0 ± 117.5
Conventional	12	473.8 ± 56.5	52.5 ± 8.4	153.3 ± 47.1	728.7 ± 103.1	934.5 ± 125.3	1408.3 ± 151.2
Difference		-88.8 ± 70.6	16.1 ± 11.4	-37.0 ± 53.2	-122.7 ± 140.9	-143.5 ± 160.1	-232.3 ± 191.4
p-value		*0.2226*	*0.1702*	*0.4948*	*0.3937*	*0.3802*	*0.2385*

[a] Live and Dead standing include all trees with dbh ≥10 cm and ≥3 m in height.

[b] Stumps are dead and standing trees ≥0.3 and <3 m in height with a top diameter ≥10 cm.

[c] CWD includes portions of all windfalls and dead-wood pieces within the fixed-area plot with either a dbh or small-end diameter ≥10 cm.

[d] Total dead = dead standing trees + stumps + CWD.

Table 17. Total gross site volume, by stratum (mean ± SE). [a]

Study block	Plots (no.)	Stratum: Live standing trees [b] (m^3/ha)	Dead standing trees [b] (m^3/ha)	Stumps [c] (m^3/ha)	CWD [d] (m^3/ha)	Total dead [e] (m^3/ha)	Total (m^3/ha)
Both	23	988.5 ± 63.3	104.6 ± 16.2	25.2 ± 3.3	215.9 ± 24.9	345.7 ± 34.4	1334.2 ± 81.3
Mark-to-Leave	11	1000.3 ± 94.2	105.1 ± 23.6	18.8 ± 4.2	277.0 ± 42.7	401.0 ± 62.8	1401.3 ± 135.9
Conventional	12	977.6 ± 89.2	104.1 ± 23.3	31.0 ± 4.6	159.9 ± 17.9	295.0 ± 27.9	1272.6 ± 96.0
Difference		22.7 ± 129.7	1.0 ± 33.2	-12.2 ± 6.3	117.2 ± 46.3	106.0 ± 68.7	128.7 ± 166.4
p-value		*0.8628*	*0.9755*	***0.0660***	***0.0194***	*0.1377*	*0.4478*

[a] Boldface type = significantly different for an α=0.10.

[b] Live and Dead standing include all trees with dbh ≥10 cm and ≥3 m in height.

[c] Stumps are dead and standing trees ≥0.3 and <3 m in height with a top diameter ≥10 cm.

[d] CWD includes portions of all windfalls and dead-wood pieces within the fixed-area plot with either a dbh or small-end diameter ≥10 cm.

[e] Total dead = dead standing trees + stumps + CWD.

7.3 Operational Cruise Summary

7.3.1 Cruise Trees: Gross and Net Volumes

The two study blocks are similar with respect to absolute volumes and relative proportions of the five tree classes and log grades. For this reason, only the combined data are presented below. Total gross volumes from the cruise (i.e., Tree Classes A+B+C+D+E combined) are presented in **Table 18**, and net volumes are in **Table 19**. The gross and net volumes for Tree Classes A+ B+C combined are comparable to the operational cruise volumes reported in Table 3.

Tree Class A represented 89% (982 m^3/ha) of the total gross stem volume, with Tree Classes B and D representing much of the remainder (104 m^3/ha). Tree Class D, the volume of which is generally not reported in operational cruise compilations, represents 6% of the gross stem volume (64 m^3/ha). There were no trees in Tree Class E.

The higher grade logs (H+I+J combined) represented 50% (550 m^3/ha) of the total gross cruise volume. Utility Grade logs (X+U combined) represented 12% (136 m^3/ha), and the low-value/non-merchantable wood (Y+Z combined) represented 34% (374 m^3/ha) of the total. One third of the Y

Table 18. Gross cruise[a] volume, by tree class and log grade: both study blocks combined (mean ± SE).

Log grade or category	Tree Class [a]					Tree Class category [b]				
	A (m^3/ha) (%)	B (m^3/ha) (%)	C (m^3/ha) (%)	D (m^3/ha) (%)	E (m^3/ha) (%)	Undersized dead+live trees [c] (m^3/ha) (%)	B+C (m^3/ha) (%)	D+E (m^3/ha) (%)	A+B+C (m^3/ha) (%)	Total (m^3/ha) (%)
H+I+J	547.6 ± 36.9	1.1 ± 0.7	1.3 ± 0.8	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	2.5 ± 1.1	0.0 ± 0.0	550.1 ± 36.7	550.1 ± 36.7
	49	0	0	0	0	0	0	0	50	50
X+U	132.2 ± 13.2	1.4 ± 1.0	2.2 ± 1.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	3.6 ± 1.8	0.0 ± 0.0	135.8 ± 13.3	135.8 ± 13.3
	12	0	0	0	0	0	0	0	12	12
Y (≥80% sound)	89.3 ± 16.4	1.9 ± 0.9	2.6 ± 1.8	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	4.4 ± 1.9	0.0 ± 0.0	93.8 ± 16.1	93.8 ± 16.1
	8	0	0	0	0	0	0	0	8	8
Y (<80% sound)	179.1 ± 23.8	34.3 ± 10.9	5.6 ± 3.6	29.4 ± 6.6	0.0 ± 0.0	0.0 ± 0.0	39.9 ± 12.9	29.4 ± 6.6	219.0 ± 28.1	248.4. ± 29.5
	16	3	1	3	0	0	4	3	20	22
Y	268.5 ± 28.7	36.1 ± 11.1	8.2 ± 3.9	29.4 ± 6.6	0.0 ± 0.0	0.0 ± 0.0	44.3 ± 12.9	29.4 ± 6.6	312.8 ± 33.9	342.2 ± 36.2
	24	3	1	3	0	0	4	3	28	31
Z	0.0 ± 0.0	0.2 ± 0.2	0.3 ± 0.3	31.3 ± 8.0	0.0 ± 0.0	0.0 ± 0.0	0.6 ± 0.4	31.3 ± 8.0	0.6 ± 0.4	31.9 ± 7.9
	0	0	0	3	0	0	0	3	0	3
Y+Z	268.5 ± 28.7	36.3 ± 11.2	8.5 ± 3.9	60.8 ± 10.6	0.0 ± 0.0	0.0 ± 0.0	44.9 ± 13.0	60.8 ± 10.6	313.3 ± 33.9	374.1 ± 36.4
	24	3	1	5	0	0	4	5	28	34
Stumps & tops	34.1 ± 4.4	1.9 ± 0.5	0.7 ± 0.2	3.5 ± 0.6	0.0 ± 0.0	7.4 ± 1.1	2.6 ± 0.6	3.5 ± 0.6	36.7 ± 4.6	47.7 ± 4.9
	3	0	0	0	0	1	0	0	3	4
Total	982.4 ± 63.4	40.7 ± 11.7	12.7 ± 5.2	64.3 ± 11.2	0.0 ± 0.0	7.4 ± 1.1	53.5 ± 13.9	64.3 ± 11.2	1035.9 ± 65.8	1107.6 ± 69.9
	89	4	1	6	0	1	5	6	93	100

[a] Cruise includes Tree Classes A to E (≥17.5 cm dbh and ≥3 m tall).

[b] See Table 8 for descriptions of tree classes.

[c] Undersized trees = 10 to 17.4 cm dbh.

Grade volume might be considered pulp (i.e., comprises wood that is ≥80% sound)[23]. Stumps and tops combined represented 4% of the total gross cruise volume.

Close to 100% of the volume in the higher log grades (H+I+J combined) was in Tree Class A. Similarly, 98% of the gross volume in the Utility Grades (U+X combined) was in Tree Class A. Tree Classes B and C included only 2% of the mean total Utility-Grade gross volume. Tree Classes B and C include only 6 m^3/ha of gross volume in Utility-Grade-and-better (X grade and better). Tree Class D did not include Utility-Grade-and-better logs.

On average, 78% of the Y Grade gross volume was in Tree Class A. Tree Classes B, C, and D combined represented 22% of the total Y Grade volume, with 98% of this volume being in the lower end of the range in terms of quality (<80% sound) and value. (Upper-range Y Grade wood, i.e., ≥80% sound, occurred only in Tree Classes B and C. The Z Grade wood volume was present only in Tree Class D).

7.3.2 *Cruise Values*

Table 20 presents average market value of logs ($/ha) by tree class and log grade. These values are based on average log prices for the Vancouver market for the six months ending 15 October 2000 as determined by the Council of Forest Industries[24].

Tree Class A represented 96% of the estimated total cruise value **(Table 21)**. The highest graded logs represented 71% of the total cruise value. The Utility Grade logs (X+U combined) represented

[23] Much of the ≥80% group gross volume is better than 80% sound. On average the <80% sound group gross volume is close to 50% sound. Factors such as piece size and market conditions would determine whether or not the <80% group net volume would be used as pulp.

[24] Jim Wilson, Manager, Cruise Compilation Department, Olympic Resource Management, 300–475 W. Georgia Street, Vancouver, BC; personal communication, March 2001.

Table 19. Cruise[a] net volume, by tree class and log grade: both study blocks combined (mean ± SE).

Log grade or category	Tree Class [a]					Tree Class category [b]				
	A (m^3/ha) (%)	B (m^3/ha) (%)	C (m^3/ha) (%)	D (m^3/ha) (%)	E (m^3/ha) (%)	Undersized dead+live trees [c] (m^3/ha) (%)	B+C (m^3/ha) (%)	D+E (m^3/ha) (%)	A+B+C (m^3/ha) (%)	Total (m^3/ha) (%)
H+I+J	507.6 ± 33.9	1.0 ± 0.7	1.3 ± 0.7	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	2.3 ± 1.0	0.0 ± 0.0	509.9 ± 33.7	509.9 ± 33.7
	59	0	0	0	0	0	0	0	60	60
X+U	123.5 ± 11.9	1.3 ± 0.9	2.0 ± 1.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	3.2 ± 1.6	0.0 ± 0.0	126.8 ± 11.9	126.8 ± 11.9
	14	0	0	0	0	0	0	0	15	15
Y (≥80% sound)	81.9 ± 14.7	1.6 ± 0.8	2.3 ± 1.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	3.8 ± 1.7	0.0 ± 0.0	85.7 ± 14.5	85.7 ± 14.5
	10	0	0	0	0	0	0	0	10	10
Y (<80% sound)	98.5 ± 12.7	18.6 ± 6.1	3.9 ± 2.5	11.5 ± 2.8	0.0 ± 0.0	0.0 ± 0.0	22.5 ± 7.3	11.5 ± 2.8	120.9 ± 16.0	132.4 ± 16.6
	12	2	0	1	1	0	3	1	14	15
Y	180.3 ± 19.8	20.1 ± 6.3	6.2 ± 2.8	11.5 ± 2.8	0.0 ± 0.0	0.0 ± 0.0	26.3 ± 7.4	11.5 ± 2.8	206.6 ± 23.5	218.1 ± 24.5
	21	2	1	1	0	0	3	1	24	26
Z	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	0	0	0	0	0	0	0	0	0	0
Y+Z	180.3 ± 19.8	20.1 ± 6.3	6.2 ± 2.8	11.5 ± 2.8	0.0 ± 0.0	0.0 ± 0.0	26.3 ± 7.4	11.5 ± 2.8	206.6 ± 23.5	218.1 ± 24.5
	21	2	1	1	0	0	3	1	24	26
Stumps & tops	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	0	0	0	0	0	0	0	0	0	0
Total	811.5 ± 52.4	22.4 ± 6.4	9.4 ± 4.1	11.5 ± 2.8	0.0 ± 0.0	0.0 ± 0.0	31.8 ± 8.0	11.5 ± 2.8	843.3 ± 53.7	854.8 ± 54.9
	95	3	1	1	0	0	4	1	99	100

[a] Cruise includes Tree Classes A to E (≥17.5 cm dbh and ≥3m tall).

[b] See Table 8 for descriptions of tree classes.

[c] Undersized trees = 10 to 17.4 cm dbh.

11% of the total, while Y Grade logs represented 18% of the total cruise value. The value of the Y Grade logs was fairly evenly divided between the two classes of Y Grade.

For this stand, the value of the total dead stem wood (Tree Classes B+C+D combined) was <4% of the total cruise value, with <1% of the total dead stem value in Utility-Grade-and-better logs (X Grade and better). Utility-Grade-and-better logs represented 6 m^3/ha, which is well within the avoidable waste benchmark volumes. The total dead stem wood gross volume, however, is only equal to 118 m^3/ha. This is approximately one-third of the gross volume of the combined Y and Z grade logs (374 m^3/ha).

7.4 Total Gross Site Volume, by Stratum and Log Grade

Table 22 summarizes the differences between gross and net volumes/ha of the study blocks by log grade. Because there were no significant differences between blocks (i.e., *Prob.* >>0.1), the total gross volume partitioned by grade is presented for the combined blocks in Tables 23 and 24 (data for individual blocks are provided in Appendix C). The small sample sizes preclude testing for significant differences for all grades. **Figure 7** is a visual presentation of **Table 23**.

The total gross volumes and net volumes for Utility-Grade-and-better (H+I+J and X+U categories) and for low-value/non-merchantable grades (Y+Z combined) were not significantly different between blocks. For the combined blocks, total gross volume of low-value/non-merchantable wood was 599 m^3/ha, which represents 46% of gross volume/ha for the total site (based on Table 22 which excludes stumps and tops).

The live trees, i.e., Tree Class A, represent the highest source of Y+Z volume. The total volume/ha for Y+Z wood is partitioned as follows: Tree Class A, 45%; Tree Classes B+D combined, 16%; CWD (C+E+other combined) 35%; and stumps, 4%.

Table 20. Market value, by tree class and log grade: both study blocks combined (mean ± SE).

Log Grade or category	Tree Class [a]					Tree Class category [a]				
	A ($1000/ha)	B ($1000/ha)	C ($1000/ha)	D ($1000/ha)	E ($1000/ha)	Undersized dead + live ($1000/ha)	B+C ($1000/ha)	D+E ($1000/ha)	A+B+C ($1000/ha)	Total ($1000/ha)
H+I+J	37.1 ± 2.7	0.1 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	37.3 ± 2.7	37.3 ± 2.7
X+U	5.4 ± 0.5	0.1 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.1	0.0 ± 0.0	5.5 ± 0.5	5.5 ± 0.5
Y (≥80% sound)	3.6 ± 0.6	0.1 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.1	0.0 ± 0.0	3.7 ± 0.6	3.7 ± 0.6
Y (<80% sound)	4.3 ± 0.6	0.8 ± 0.3	0.2 ± 0.1	0.5 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	1.0 ± 0.3	0.5 ± 0.1	5.3 ± 0.7	5.9 ± 0.8
Y	7.9 ± 0.8	0.9 ± 0.3	0.3 ± 0.1	0.5 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	1.2 ± 0.3	0.5 ± 0.1	9.1 ± 1.0	9.6 ± 1.0
Z	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Y+Z	7.9 ± 0.8	0.9 ± 0.3	0.3 ± 0.1	0.5 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	1.2 ± 0.3	0.5 ± 0.1	9.1 ± 1.0	9.6 ± 1.0
Stumps & tops	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Total	50.4 ± 3.3	1.0 ± 0.3	0.4 ± 0.2	0.5 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	1.5 ± 0.4	0.5 ± 0.1	51.9 ± 3.3	52.4 ± 3.3

[a] See Table 8 for descriptions of Tree Classes.

Table 21. % of total market value, by log grade and tree class: both study blocks combined.

Log Grade or category	Tree Class [a]				Tree Class category [a]		
	A (%)	B (%)	C (%)	D [b] (%)	B+C (%)	A+B+C (%)	Total (%)
H+I+J	71	0	0	0	0	71	71
X+U	10	0	0	0	0	11	11
Y (≥80% sound)	7	0	0	0	0	7	7
Y (<80% sound)	8	2	0	1	2	10	11
Y	15	2	1	1	2	17	18
Z	0	0	0	0	0	0	0
Y+Z	15	2	1	1	2	17	18
Stumps and tops	0	0	0	0	0	0	0
Total	96	2	1	1	3	99	100

[a] See Table 8 for descriptions of Tree Classes.
[b] There were no trees in Tree Class E.

Table 22. Total gross site volume and net site volume, for all strata combined (excluding stumps and tops) (mean ± SE). [a]

Variable, and study block	Plots (no.)	Log Grade category H+I+J (m^3/ha)	X+U (m^3/ha)	Y+Z (m^3/ha)
Volume				
Both	23	550.4 ± 36.7	137.8 ± 13.3	599.6 ± 47.1
Mark-to-Leave	11	577.3 ± 56.1	136.9 ± 16.2	636.9 ± 85.7
Conventional	12	525.7 ± 49.5	138.7 ± 21.8	565.4 ± 46.2
Difference		51.6 ± 74.8	-1.8 ± 27.3	71.5 ± 97.8
p-value		*0.4979*	*0.9478*	*0.4708*
Net volume				
Both	23	510.3 ± 33.7	129.1 ± 12.0	232.7 ± 24.7
Mark-to-Leave	11	531.7 ± 50.5	131.8 ± 15.6	240.8 ± 44.7
Conventional	12	490.7 ± 46.6	126.6 ± 18.7	225.2 ± 25.5
Difference		41.0 ± 68.7	5.3 ± 24.4	15.7 ± 51.4
p-value		*0.5574*	*0.8315*	*0.7639*

[a] Table 22 includes all strata as per Table 23, i.e., standing live and dead trees (except stumps and tops), CWD (Tree classes C+E and "other"), and stumps (short snags <3.0 m).

7.5 "Potential" Sources of Post-Harvest CWD: Attributes of Pre-Harvest CWD and Low-Value/Non-Merchantable Wood in the Stand

Potential sources of post-harvest CWD on site prior to harvesting include:

1. low-value/non-merchantable wood in dead down trees (i.e., Tree Classes C and E) and other CWD pieces, and
2. low-value/non-merchantable wood in standing live and dead trees (i.e., Tree Classes A, B, and D).

For the purpose of this report all non-merchantable wood (i.e., wood quality less than the criteria for Y Grade) has been classified as Z grade wood. As shown in **Table 23** less than 10 m^3/ha of original CWD was classified as Tree Class C [25]. Y and Z Grade wood comprised almost all of this volume. Because

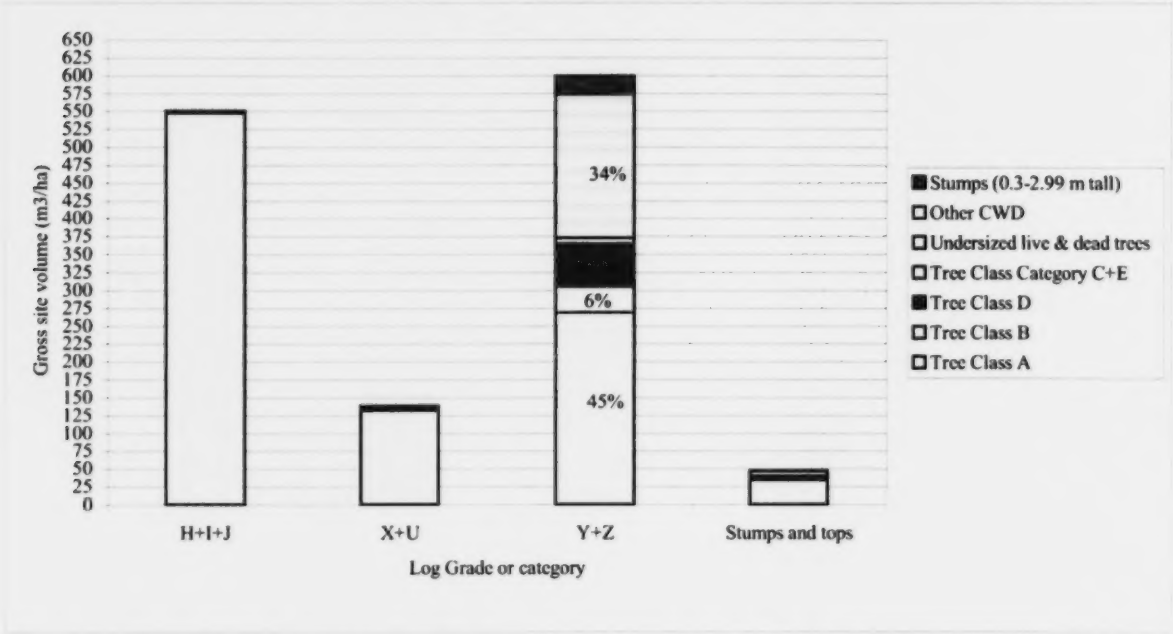


Figure 5. Total gross site volume, by stratum and log grade.

Table 23. Total gross site volume partitioned by tree class, stratum, and log grade: both study blocks combined (mean ± SE).

Category [a]	Log grade category				
	H+I+J (m^3/ha)	X+U (m^3/ha)	Y+Z (m^3/ha)	Stumps [d] and tops (m^3/ha)	Total (m^3/ha)
Tree Class A - Live Stem	547.6 ± 36.9	132.3 ± 13.3	268.5 ± 28.7	34.1 ± 4.4	982.5 ± 63.4
Tree Class B - Dead Potential Standing (>50% sound)	1.1 ± 0.7	1.4 ± 1.0	36.3 ± 11.2	1.8 ± 0.4	40.7 ± 11.6
Tree Class D - Dead Useless Standing (<50% sound)	0.0 ± 0.0	0.0 ± 0.0	59.7 ± 10.7	3.4 ± 0.6	63.1 ± 11.3
Undersized dead+live trees [b]	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	7.2 ± 1.1	7.2 ± 1.1
CWD					
Windfalls (Tree Classes C+E combined) [c]	0.0 ± 0.0	1.6 ± 0.9	8.1 ± 3.1	0.0 ± 0.0	9.8 ± 3.5
Other CWD Pieces	1.7 ± 0.9	2.3 ± 1.2	202.0 ± 22.9	0.0 ± 0.0	206.0 ± 23.0
Stumps (<3.0 m tall) [f]	0.0 ± 0.0	0.2 ± 0.1	25.0 ± 3.3	0.0 ± 0.0	25.2 ± 3.3
Total	550.4 ± 36.7	137.8 ± 13.3	599.6 ± 47.1	46.6 ± 4.8	1334.4 ± 81.3

[a] See Table 8 for definitions of Weyerhaeuser's tree classes.
[b] Undersized trees = 10-17.4 cm dbh.
[c] The ecological definition of CWD included dead fallen trees such as Tree Classes C and E. For Tree Classes C and E the volume assigned to CWD is that portion of log within the plot, not the entire tree. In contrast, the cruise volumes for Tree Classes C and E are based on the entire tree.
[d] A stump refers to the portion of the tree bole <0.3 m in height for both standing live and dead trees. It does not include the stump, i.e., <0.3 m of dead standing stems which are ≥0.3 m and <3 m in height, i.e., short snags. In this report, these short snags are referred to as stump (see Footnote F).
[e] For the purpose of the pilot study, dead down wood not meeting the criteria of a Y or better grade was classified as a Z grade.
[f] In this report a short snag is referred to as a stump because a dead tree <3.0 m in height is not recorded in an operational cruise, but is recorded as a stump in a Residue and Waste Survey.

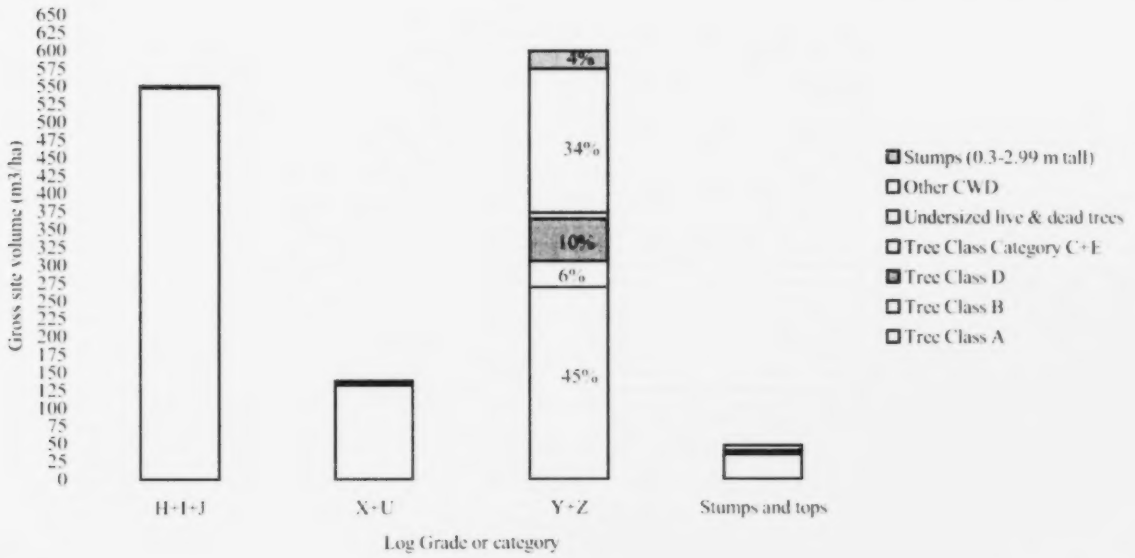


Figure 5. Total gross site volume, by stratum and log grade.

Table 23. Total gross site volume partitioned by tree class, stratum, and log grade: both study blocks combined (mean ± SE).

Category [a]	Log grade category				
	H+I+J (m^3/ha)	X+U (m^3/ha)	Y+Z (m^3/ha)	Stumps [d] and tops (m^3/ha)	Total (m^3/ha)
Tree Class A - Live Stem	547.6 ± 36.9	132.3 ± 13.3	268.5 ± 28.7	34.1 ± 4.4	982.5 ± 63.4
Tree Class B - Dead Potential Standing (>50% sound)	1.1 ± 0.7	1.4 ± 1.0	36.3 ± 11.2	1.8 ± 0.4	40.7 ± 11.6
Tree Class D - Dead Useless Standing (<50% sound)	0.0 ± 0.0	0.0 ± 0.0	59.7 ± 10.7	3.4 ± 0.6	63.1 ± 11.3
Undersized dead+live trees [b]	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	7.2 ± 1.1	7.2 ± 1.1
CWD					
Windfalls (Tree Classes C+E combined) [c]	0.0 ± 0.0	1.6 ± 0.9	8.1 ± 3.1	0.0 ± 0.0	9.8 ± 3.5
Other CWD Pieces	1.7 ± 0.9	2.3 ± 1.2	202.0 ± 22.9	0.0 ± 0.0	206.0 ± 23.0
Stumps (<3.0 m tall) [d]	0.0 ± 0.0	0.2 ± 0.1	25.0 ± 3.3	0.0 ± 0.0	25.2 ± 3.3
Total	550.4 ± 36.7	137.8 ± 13.3	599.6 ± 47.1	46.6 ± 4.8	1334.4 ± 81.3

[a] See Table 8 for definitions of Weyerhaeuser's tree classes.

[b] Undersized trees = 10-17.4 cm dbh.

[c] The ecological definition of CWD included dead fallen trees such as Tree Classes C and E. For Tree Classes C and E the volume assigned to CWD is that portion of log within the plot, not the entire tree. In contrast, the cruise volumes for Tree Classes C and E are based on the entire tree.

[d] A stump refers to the portion of the tree bole ≥ 0.3 m in height for both standing live and dead trees. It does not include the stump, i.e., < 0.3 m of dead standing stems which are ≥0.3 m and < 3 m in height, i.e., short snags. In this report, these short snags are referred to as stump (see Footnote [e]).

For the purpose of the pilot study, dead down wood not meeting the criteria of a Y or better grade was classified as a Z grade.

In this report a short snag is referred to as a stump because a dead tree < 3.0 m in height is not recorded in an operational cruise, but is recorded as a stump in a Residue and Waste Survey.

Table 24. % of total gross site volume, by stratum and log grade: both study blocks combined.

Category [a]	Log grade category					
	H+I+J (% of total vol.)	X+U (% of total vol.)	Y+Z (% of total vol.)	Stumps[d] and tops (% of total vol.)	Total (% of total vol.	Y+Z (% of volume in category)
Tree Class A - Live Stem	41	10	20	3	74	45
Tree Class B - Dead Potential Standing (>50% sound)	0	0	3	0	3	6
Tree Class D - Dead Useless Standing (<50% sound)	0	0	4	0	5	10
Undersized dead+live trees [b]	0	0	0	1	1	0
CWD						
Windfalls (Tree Classes C+E combined) [c]	0	0	1	0	1	1
Other CWD Pieces	0	0	15	0	15	34
Stumps (<3.0 m tall)	0	0	2	0	2	4
Total	41	10	45	4	100	100

[a] See Table 8 for definitions of Weyerhaeuser's tree classes.
[b] Undersized trees = 10 to 17.4 cm dbh.
[c] The ecological definition of CWD included dead fallen trees such as Tree Classes C and E. For Tree Classes C and E the volume assigned to CWD is that portion of log within the plot, not the entire tree. In contrast, the cruise volumes for Tree Classes C and E are based on the entire tree.
[d] Stumps include standing and fallen trees; excludes dead standing stumps ≥0.3 m and <3.0 m in height (i.e., short snags).
[e] For the purpose of the pilot study, dead down wood not meeting the criteria of a Y or better grade was classified as a Z grade.

only 1% of the pre-harvest CWD was Utility-Grade-and-better, the following paragraphs discuss the attributes of all the CWD as a whole, i.e., windfalls and "other" CWD combined.

7.5.1 Attributes of Pre-Harvest CWD

Diameter and Length Classes

Tables 25 and **26**, respectively, present the diameter and length class means and standard errors of the number of pieces/ha and volume/ha, and the corresponding percentages of the totals. Tables 25 and 26 also present the *p-values* for comparing blocks in terms of differences in the total density and total volume/ha in each diameter and length class.

Even though the total number of pieces/ha did not differ significantly between blocks, the diameter and length distributions vary. The Conventional Block had a slightly higher density of pieces in the ≤3-m length class and in the ≤30-cm diameter class. The Mark-to-Leave Block had a higher density of pieces in the >10-m and >14-m length classes, in particular pieces with a large-end diameter >65 cm. The differences between blocks were statistically significant for the >14-m length class total. The high within-block variability may, however, obscure other differences; in particular, differences in the total density of pieces ≤3 m long.

As expected, the smallest diameter and length classes represent from 65 to 84% of the total number of pieces/ha. The largest diameter pieces (large-end diameter >65 cm) represent 9–11%, while the longer pieces (>10 m long) represent 7–12% of the total pieces/ha. Those pieces with a large-end diameter >65 cm and a length >10 m represent 2–5% of the total number of pieces/ha. This component translates into an average of 12 and 32 pieces/ha for the Conventional and Mark-to-Leave Blocks respectively.

The total volume for the Conventional Block was significantly lower than the total volume for the Mark-to-Leave Block. This difference largely reflects the significantly higher mean volume/ha in the >10-m length and >65-cm large-end diameter classes of the Mark-to-Leave Block compared to the Conventional Block. For the Mark-to-Leave Block, volume/ha in the class combining the above diameter and length classes was noticeably higher than mean for the Conventional Block. The above finding reflects a higher density of large pieces, in particular long pieces, in the Mark-to-Leave Block. The mean volume/ha in the smallest diameter and length classes were generally comparable between the two blocks.

As expected, the larger diameter and longer length classes represent much of the total volume/ha. The smallest diameter and shortest length classes represented <15% of the total block volumes/ha. The larger diameter classes (>65-cm large-end diameter) represented 53–71% and, the upper length classes (>10 m long) represented 54–70%, of the total volume/ha, respectively, for the Conventional and Mark-to-Leave Blocks. Together these classes represented 31% of the total mean volume/ha for the Conventional Block, and 56% for the Mark-to-Leave Block. These values correspond to an average 50 m^3/ha for the Conventional

[25] There were no trees in Tree Class E.

Table 25. Density of CWD (includes Tree Classes C+E + other combined), partitioned by diameter and length classes (mean ± SE).[a]

Diameter class	Study block	≤3 m (no. pieces/ha) (%)	3-10 m (no. pieces/ha) (%)	>10 m (no. pieces/ha) (%)	>14 m (no. pieces/ha) (%)	Total (no. pieces/ha) (%)	Difference (no. pieces/ha)	*p-value*
≤30 cm	Mark-to-Leave	343.0 ± 81.4	66.3 ± 14.6	9.0 ± 6.9	1.5 ± 0.9	418.3 ± 85.0	-90.0 ± 122.0	*0.4688*
		57	11	1	0	69		
	Conventional	435.6 ± 81.9	58.5 ± 12.2	14.1 ± 4.5	1.3 ± 1.2	508.2 ± 87.5		
		60	8	2	0	70		
30-65 cm	Mark-to-Leave	41.2 ± 21.6	46.5 ± 5.4	34.2 ± 8.3	21.9 ± 8.1	121.9 ± 29.3	-36.1 ± 35.4	*0.3191*
		6	8	6	4	20		
	Conventional	**86.3 ± 20.3**	47.5 ± 5.4	24.2 ± 4.2	12.9 ± 2.6	157.9 ± 19.8		
		11	7	3	2	21		
>65 cm	Mark-to-Leave	9.3 ± 4.4	24.7 ± 5.8	**32.0 ± 4.7**	**26.1 ± 4.9**	65.9 ± 12.3	3.4 ± 14.1	*0.8120*
		2	4	5	4	11		
	Conventional	14.1 ± 3.4	36.2 ± 6.6	12.2 ± 3.5	7.1 ± 2.9	62.5 ± 6.9		
		2	5	2	1	9		
>75 cm	Mark-to-Leave	3.6 ± 2.6	20.0 ± 4.3	**25.1 ± 4.0**	**21.3 ± 3.8**	48.8 ± 8.4	14.3 ± 9.5	*0.1483*
		1	3	4	3	8		
	Conventional	6.3 ± 2.1	19.2 ± 4.9	9.1 ± 2.8	5.1 ± 2.0	34.5 ± 4.4		
		1	3	1	1	5		
Total	Mark-to-Leave	393.5 ± 89.1	137.4 ± 17.4	**75.1 ± 12.2**	**49.5 ± 10.9**	606.0 ± 96.0		
		65	23	12	8	100		
	Conventional	535.9 ± 95.7	142.3 ± 19.7	50.5 ± 8.5	21.2 ± 5.0	728.7± 103.1		
		73	20	7	3	100		
Difference		-142.5 ± 130.7	-4.8 ± 26.3	24.6 ± 14.9	28.3 ± 12.0	-122.7 ± 140.9		
p-value		*0.2881*	*0.8557*	*0.1136*	***0.0280***	*0.3937*		

[a] *p-values* in italic boldface are significantly different for an α=0.1. Items in boldface type are noticeably higher. Sample size precluded testing for significant differences.

Block and 153 m^3/ha for the Mark-to-Leave Block. The higher volumes in the Mark-to-Leave Block do not appear to be related to the different timber types in the blocks.

Diameter and Decay Classes

Tables 27 and **28** present CWD density and volume/ha by diameter and decay classes. The broad groupings for decay class are similar to those proposed by Parks et al. (1997). A brief description from Parks et al. (1997) follows:

- Slightly Decayed logs represent those trees that have just fallen over, retain their bark and branches, have little decay in the wood, and are resting largely above the ground
- Moderately Decayed logs represent those logs that are in contact with the ground, have lost some of their bark and branches, and have some decay in the wood.
- Well Decayed logs represent those logs that have begun decomposing into the forest floor, are not intact, are extensively decayed, and lack both limbs and bark.

For both study blocks, ≥90% of pieces and volume was Moderately to Well Decayed, although the relative proportions in Decay Classes 3 and 4+5 differed between study blocks.

The Conventional Block had a significantly higher total density of pieces in Decay Classes 4+5 combined (67%) compared to the Mark-to-Leave Block (34%). This trend was observed in all diameter classes but was most noticeable for pieces with a small or medium large-end diameter (i.e., <65 cm at the large end). In contrast, the Mark-to-Leave Block had a high, although not significantly high, total density of pieces in Decay Class 3 (56%). The greater density was most noticeable for the small and large diameter classes.

Table 26. Volume of CWD (includes Tree Classes C+E + other combined), partitioned by diameter and length classes (mean ± SE). [a]

Diameter class	Study block	≤3 m (no. pieces/ha) (%)	3-10 m (no. pieces/ha) (%)	>10 m (no. pieces/ha) (%)	>14 m (no. pieces/ha) (%)	Total (no. pieces/ha) (%)	Difference (no. pieces/ha)	*p-value*
≤30 cm	Mark-to-Leave	5.4 ± 1.4	7.0 ± 1.6	2.3 ± 1.6	0.8 ± 0.5	14.7 ± 3.5	-4.0 ± 4.6	*0.3937*
		2	2	1	0	5		
	Conventional	6.5 ± 1.1	7.2 ± 2.0	4.9 ± 1.9	0.4 ± 0.4	18.7 ± 3.0		
		4	5	3	0	12		
30-65 cm	Mark-to-Leave	4.3 ± 1.3	24.4 ± 4.6	37.5 ± 6.1	22.0 ± 5.5	66.1 ± 7.9	9.0 ± 10.9	*0.4150*
		2	9	13	8	24		
	Conventional	8.3 ± 1.0	17.0 ± 2.2	31.8 ± 6.5	22.0 ± 5.0	57.1 ± 7.5		
		5	11	20	14	36		
>65 cm	Mark-to-Leave	3.7 ± 1.7	38.8 ± 14.4	**153.8 ± 27.0**	**141.7 ± 26.6**	**196.3 ± 38.4**	112.1 ± 41.0	*0.0125*
		1	14	56	51	71		
	Conventional	3.7 ± 1.1	31.2 ± 7.4	49.2 ± 16.2	37.5 ± 15.2	84.2 ± 14.6		
		2	19	31	23	52		
>75 cm	Mark-to-Leave	1.5 ± 1.1	32.7 ± 11.1	**129.3 ± 24.0**	**120.7 ± 23.2**	**163.5 ± 32.7**	101.9 ± 35.2	*0.0086*
		1	12	47	44	59		
	Conventional	1.1 ± 0.4	19.4 ± 5.2	41.1 ± 13.8	30.4 ± 12.2	61.6 ± 13.0		
		1	12	26	19	39		
Total	Mark-to-Leave	13.3 ± 3.1	70.2 ± 17.6	**193.5 ± 28.8**	**164.5 ± 27.1**	**277.0 ± 42.7**		
		5	25	70	59	100		
	Conventional	18.4 ± 2.3	55.5 ± 9.9	86.0 ± 19.5	59.9 ± 17.4	159.9 ± 17.9		
		11	35	54	37	100		
Difference		-5.1 ± 3.8	14.7 ± 20.2	107.6 ± 34.7	104.6 ± 32.2	117.2 ± 46.3		
p-value		*0.1992*	*0.4755*	***0.0055***	***0.0038***	***0.0194***		

[a] *p-values* in italic boldface are significantly different for an α=0.1. Items in boldface type are noticeably higher. Sample size precluded testing for significant differences.

The total volumes for Decay Classes 4+5 combined were comparable for the two blocks. Even though the total density of Decay Class 3 in Conventional Block was significantly higher than that for the Mark-to-Leave Block, the pieces in the Mark-to-Leave Block were larger in comparison. Therefore, the Mark-to-Leave Block has fewer but larger Well-Decayed pieces. For the Mark-to-Leave Block, the total volume/ha in Decay Class 3 was also significantly higher than the mean in Conventional Block. This difference was due to the higher total density, and a higher density of larger diameter pieces, associated with the Mark-to-Leave Block.

7.5.2 Potential Low-Value/Non-Merchantable Wood in Tree Classes A, B, and D

Tables 29 and **30**, respectively, present by block the density and volume of pieces derived from standing live and dead trees by grade. Small sample sizes preclude significance testing for each grade, diameter, and length combination. However, neither the mean density nor the volume/ha of the potential low-value/non-merchantable large pieces (i.e., >65 cm at the large-end and >10 m in length) derived from Tree Classes A, B and D is significantly different between the two blocks **(Table 31)**.

The mean density for the >65 cm and >10 m potential low-value/non-merchantable wood (i.e., Grades Y+Z combined) derived from Tree Classes A, B, and D combined is 29 pieces/ha for the Mark-to-Leave Block and 31 pieces/ha for the Conventional Block. The mean volume/ha for these larger low-value/non-merchantable pieces is 207 m^3/ha for the Mark-to-Leave Block, and 252 m^3/ha Conventional Block.

The potential availability of large-sized Utility-Grade logs (U+X Grades combined) in Tree Classes A, B, and D combined, is noticeably lower than that of the combined Y+Z Grade logs.

Table 27. Density of CWD (includes Tree Classes C+E + other combined), partitioned by diameter and decay classes (mean ± SE).

Diameter class	Study block	Decay Class 1+2, Slightly Decayed (no. pieces/ha) (%)	3, Moderately Decayed (no.pieces/ha) (%)	4+5, Well Decayed (no. pieces/ha) (%)	Total (no. pieces/ha) (%)
≤30 cm	Mark-to-Leave	40.3 ± 21.5	262.2 ± 58.7	115.8 ± 38.2	418.3 ± 85.0
		7	43	19	69
	Conventional	35.7 ± 11.9	148.9 ± 58.5	**323.7 ± 85.9**	508.2 ± 87.5
		5	21	44	70
30-65 cm	Mark-to-Leave	16.7 ± 8.4	51.9 ± 16.8	53.3 ± 8.2	121.9 ± 29.3
		3	8	9	20
	Conventional	5.3 ± 2.4	39.1 ± 4.3	**113.6 ± 21.9**	157.9 ± 19.8
		1	5	16	22
>65 cm	Mark-to-Leave	2.0 ± 1.3	**27.5 ± 6.5**	**36.5 ± 6.8**	**65.9 ± 12.3**
		0	5	6	11
	Conventional	0.7 ± 0.6	9.9 ± 3.4	**51.9 ± 8.0**	62.5 ± 6.9
		0	1	7	8
>75 cm	Mark-to-Leave	1.0 ± 1.0	**19.8 ± 4.5**	**27.9 ± 5.1**	**48.8 ± 8.4**
		0	3	5	8
	Conventional	0.6 ± 0.6	4.9 ± 2.5	28.9 ± 5.2	34.5 ± 4.4
		0	1	4	5
Total	Mark-to-Leave	59.0 ± 22.1	**341.5 ± 63.5**	**205.6 ± 42.6**	**606.0 ± 96.0**
		10	56	34	100
	Conventional	41.7 ± 13.1	197.9 ± 60.8	489.1 ± 101.2	728.7 ± 103.1
		6	27	67	100
Difference		17.3 ± 25.7	143.6 ± 87.9	**-283.6 ± 109.8**	-122.7 ± 140.9
p-value		*0.5076*	*0.1171*	***0.0173***	***0.3937***

[a] *p-values* in italic boldface are significantly different for an α=0.1. Items in boldface type are noticeably higher. Sample size precluded testing for significant differences.

The mean density of large Utility-Grade logs is 8 and 5 pieces/ha respectively for the Mark-to-Leave and Conventional Blocks. The corresponding mean volume for these large Utility-Grade logs is 41 and 23 m^3/ha respectively for the Mark-to-Leave and Conventional Blocks (Tables 29 and 30).

8 DISCUSSION AND CONCLUSIONS

8.1 Potential Sources of CWD

Under the current provincial utilization standards for the British Columbia Coast (BCMOF 1997), opportunities for Licensees to leave wood in the setting without monetary billing are strongly tied to the timber attributes and pulp market prices. The stand must include low-value/non-merchantable wood, i.e., Y and Z Grade pieces, and market prices must be low enough that leaving pulp wood in the setting is more economical than yarding and processing the logs. The pilot site was chosen for study because the stand contained considerable decay and potential waste. At the time of the study, Y and Z Grade logs and benchmark wood volumes were being left on site as part of Weyerhaeuser's standard operations[26].

Based on the review of the attributes (i.e., size and volume) of low value/non-merchantable wood in the pre-harvest CWD and standing timber, it appears that, for the pilot site, there is a potential in the Mark-to-Leave Block to retain, at the time of

Table 28. Volume of CWD (includes Tree Classes C+E + other combined), partitioned by diameter and decay classes (mean ± SE).

Diameter class	Study block	Decay Class 1+2, Slightly Decayed (m^3/ha) (%)	3, Moderately Decayed (m^3/ha) (%)	4+5, Well Decayed (m^3/ha) (%)	Total (m^3/ha) (%)
≤30 cm	Mark-to-Leave	2.7 ± 1.4	7.5 ± 2.1	4.5 ± 0.9	14.7 ± 3.5
		1	3	1	5
	Conventional	4.2 ± 1.9	6.1 ± 1.3	8.3 ± 2.3	18.7 ± 3.0
		3	4	5	12
30-65 cm	Mark-to-Leave	10.8 ± 3.8	31.6 ± 6.2	23.7 ± 4.8	66.1 ± 7.9
		4	11	9	24
	Conventional	4.4 ± 2.1	28.4 ± 4.3	24.3 ± 3.8	57.1 ± 7.5
		3	18	15	36
>65 cm	Mark-to-Leave	11.9 ± 7.5	**115.4 ± 25.1**	69.0 ± 20.2	**196.3 ± 38.4**
		4	42	25	71
	Conventional	3.8 ± 3.2	31.8 ± 13.4	48.6 ± 14.2	84.2 ± 14.6
		2	20	30	52
>75 cm	Mark-to-Leave	5.9 ± 5.5	**95.5 ± 22.4**	62.2 ± 20.4	**163.5 ± 32.7**
		2	34	23	59
	Conventional	3.4 ± 3.2	23.4 ± 11.0	34.8 ± 12.7	61.6 ± 13.0
		2	15	22	39
Total	Mark-to-Leave	**25.4 ± 7.8**	**154.5 ± 27.3**	97.2 ± 21.6	**277.0 ± 42.7**
		9	56	35	100
	Conventional	12.4 ± 4.5	66.3 ± 13.9	81.2 ± 16.8	159.9 ± 17.9
		8	42	50	100
Difference		13.0 ± 9.0	**88.2 ± 30.7**	16.0 ± 27.4	**117.2 ± 46.3**
p-value		*0.1641*	***0.0091***	*0.5644*	***0.0194***

* *p-values* in italic boldface are significantly different for an α=0.1. Items in boldface type are noticeably higher. Sample size precluded testing for significant differences.

harvest, dead down wood volumes that are comparable to the original pre-harvest total dead wood volume. This assertion is based on the following:

- The estimated pre-harvest total gross volume/ha of low-value/non-merchantable wood (Y+Z Grades combined) for all strata is three quarters higher than the total pre-harvest dead wood volume (599 vs. 346 m^3/ha).
- Approximately two-thirds of the pre-harvest total gross volume of low-value/non-merchantable wood is derived from the live and dead standing trees. As a general rule, this source of dead wood will be less susceptible to breakage than Moderately Decayed or Well-Decayed CWD on the ground at the time of harvest.
- The volume and density of large-sized (i.e., ≥65 cm at the large-end and ≥10 m in length) low-value/non-merchantable wood (Grades Y and Z combined) in the standing live and dead trees, is estimated at densities and volumes/ha comparable to, or higher than those of the pre-harvest CWD.

The above estimates of the pilot site's pre-harvest attributes are at best an approximation of the total, low-value/non-merchantable wood that can potentially be retained at the time of harvest. In fact, only a portion of this "potential" wood will be left—even in the Mark-to-Leave Block, where Y and Z Grades of wood are bucked off and marked to leave. Numerous fac-

[29] Mike Richardson, General Foreman, Weyerhaeuser's North Island Timberlands Division; personal communication, summer 2001.

Table 29. Density of "potential" logs in standing trees (Tree Class category A+B+D and undersized trees), by log grade and study block (mean ± SE). *

Study block	Diameter class	Length class	Log Grade or category: H+I+J (no. pieces/ha)	X+U (no. pieces/ha)	V (≥80% sound) (no. pieces/ha)	Y (<80% sound) (no. pieces/ha)	Y (no. pieces/ha)	Z (no. pieces/ha)	Y+Z (no. pieces/ha)	Stumps & tops (no. pieces/ha)	Total (no. pieces/ha)
Mark-to-Leave	<30 cm	≤3 m	0.0 ± 0.0	11.8 ± 3.7	51.8 ± 8.9	0.0 ± 0.0	51.8 ± 8.9	0.0 ± 0.0	51.8 ± 8.9	0.0 ± 0.0	63.6 ± 10.5
		3.1-10 m	13.6 ± 5.8	115.9 ± 20.1	22.7 ± 4.2	9.1 ± 3.6	31.8 ± 4.0	0.0 ± 0.0	31.8 ± 4.0	0.0 ± 0.0	161.4 ± 24.7
		>10 m	0.9 ± 0.9	0.9 ± 0.9	0.9 ± 0.9	0.0 ± 0.0	0.9 ± 0.9	0.0 ± 0.0	0.9 ± 0.9	0.0 ± 0.0	2.7 ± 2.5
		Total	14.6 ± 5.6	128.6 ± 21.4	75.5 ± 8.8	9.1 ± 3.6	84.6 ± 10.5	0.0 ± 0.0	84.6 ± 10.5	0.0 ± 0.0	227.7 ± 33.1
	30-65 cm	≤3 m	0.0 ± 0.0	2.3 ± 2.1	21.8 ± 5.5	0.0 ± 0.0	21.8 ± 5.5	0.0 ± 0.0	21.8 ± 5.5	0.0 ± 0.0	24.1 ± 7.3
		3.1-10 m	33.2 ± 6.2	47.7 ± 8.2	22.7 ± 7.5	13.6 ± 4.0	36.4 ± 8.0	5.0 ± 2.6	41.4 ± 8.6	0.0 ± 0.0	122.3 ± 16.8
		>10 m	100.0 ± 13.9	14.6 ± 3.9	14.6 ± 3.6	2.3 ± 2.1	16.8 ± 4.0	0.0 ± 0.0	16.8 ± 4.0	0.0 ± 0.0	131.4 ± 14.7
		Total	133.2 ± 15.9	64.6 ± 10.7	59.1 ± 10.8	15.9 ± 3.9	75.0 ± 11.5	5.0 ± 2.6	80.0 ± 12.0	0.0 ± 0.0	277.7 ± 25.6
	>65 cm	≤3 m	0.0 ± 0.0	1.8 ± 1.1	2.7 ± 1.8	0.0 ± 0.0	2.7 ± 1.8	0.9 ± 0.9	3.6 ± 2.6	0.0 ± 0.0	5.5 ± 3.4
		3.1-10 m	26.4 ± 4.4	2.7 ± 1.3	0.0 ± 0.0	9.1 ± 2.7	9.1 ± 2.7	4.6 ± 1.9	13.6 ± 3.6	0.0 ± 0.0	42.7 ± 5.8
		>10 m	52.7 ± 6.6	8.2 ± 2.8	9.1 ± 3.7	18.2 ± 6.0	27.3 ± 7.5	1.8 ± 1.1	29.1 ± 7.2	0.0 ± 0.0	90.0 ± 10.3
		Total	79.1 ± 7.8	12.7 ± 3.6	11.8 ± 3.9	27.3 ± 5.6	39.1 ± 7.7	7.3 ± 2.8	46.4 ± 8.4	0.0 ± 0.0	138.2 ± 13.7
	Stumps & tops		0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	467.3 ± 49.8	467.3 ± 49.8
	Total	≤3 m	0.0 ± 0.0	15.9 ± 5.8	76.4 ± 11.1	0.0 ± 0.0	76.4 ± 11.1	0.9 ± 0.9	77.3 ± 11.0	0.0 ± 0.0	93.2 ± 15.4
		3.1-10 m	73.2 ± 9.9	166.4 ± 19.6	45.5 ± 9.0	31.8 ± 3.1	77.3 ± 9.1	9.6 ± 3.1	86.8 ± 9.1	0.0 ± 0.0	326.4 ± 24.7
		>10 m	153.6 ± 14.6	23.6 ± 3.8	24.6 ± 4.8	20.5 ± 6.1	45.0 ± 7.9	1.8 ± 1.1	46.8 ± 7.6	0.0 ± 0.0	224.1 ± 20.2
		Stumps & tops	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	467.3 ± 49.8	467.3 ± 49.8
		Total	226.8 ± 19.5	205.9 ± 21.3	146.4 ± 14.6	52.3 ± 6.2	198.6 ± 18.6	12.3 ± 3.8	210.9 ± 18.2	467.3 ± 49.8	1110.9 ± 90.6
Conventional	<30 cm	≤3 m	0.0 ± 0.0	42.5 ± 13.7	50.0 ± 10.6	1.7 ± 1.6	51.7 ± 10.8	0.0 ± 0.0	51.7 ± 10.8	0.0 ± 0.0	94.2 ± 22.8
		3.1-10 m	27.1 ± 9.4	110.0 ± 16.5	36.7 ± 6.5	2.1 ± 2.0	38.8 ± 6.1	0.0 ± 0.0	38.8 ± 6.1	0.0 ± 0.0	175.8 ± 18.9
		>10 m	3.8 ± 2.1	2.9 ± 2.1	0.0 ± 0.0	2.5 ± 1.7	2.5 ± 1.7	0.0 ± 0.0	2.5 ± 1.7	0.0 ± 0.0	9.2 ± 3.7
		Total	30.8 ± 10.0	155.4 ± 25.0	86.7 ± 11.4	6.3 ± 2.7	92.9 ± 12.6	0.0 ± 0.0	92.9 ± 12.6	0.0 ± 0.0	279.2 ± 38.2
	30-65 cm	≤3 m	0.0 ± 0.0	2.9 ± 2.1	13.3 ± 3.3	0.0 ± 0.0	13.3 ± 3.3	2.9 ± 2.1	16.3 ± 3.0	0.0 ± 0.0	19.2 ± 4.3
		3.1-10 m	62.5 ± 11.5	54.6 ± 6.6	37.1 ± 6.6	4.6 ± 2.1	41.7 ± 6.8	0.8 ± 0.8	42.5 ± 6.9	0.0 ± 0.0	159.6 ± 18.2
		>10 m	68.8 ± 8.1	18.8 ± 5.6	15.8 ± 5.3	7.9 ± 2.8	23.8 ± 5.3	0.0 ± 0.0	23.8 ± 5.3	0.0 ± 0.0	111.3 ± 9.9
		Total	31.3 ± 12.8	76.3 ± 8.5	66.3 ± 9.5	12.5 ± 3.4	78.8 ± 8.3	3.8 ± 2.4	82.5 ± 7.8	0.0 ± 0.0	290.0 ± 19.8
	>65 cm	≤3 m	0.0 ± 0.0	1.7 ± 1.1	1.7 ± 1.1	0.0 ± 0.0	1.7 ± 1.1	0.8 ± 0.8	2.5 ± 1.2	0.0 ± 0.0	4.2 ± 1.8
		3.1-10 m	27.5 ± 5.7	5.0 ± 1.8	1.7 ± 1.1	5.8 ± 2.5	7.5 ± 2.6	8.3 ± 2.8	15.8 ± 3.6	0.0 ± 0.0	48.3 ± 6.0
		>10 m	57.5 ± 8.1	5.0 ± 1.8	2.5 ± 1.2	27.5 ± 4.9	30.0 ± 4.8	0.8 ± 0.8	30.8 ± 4.9	0.0 ± 0.0	93.3 ± 12.0
		Total	85.0 ± 9.3	11.7 ± 3.5	5.8 ± 2.2	33.3 ± 6.2	39.2 ± 6.5	10.0 ± 3.1	49.2 ± 5.6	0.0 ± 0.0	145.8 ± 12.0
	Stumps & tops		0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	526.3 ± 60.4	526.3 ± 60.4
	Total	≤3 m	0.0 ± 0.0	47.1 ± 13.7	65.0 ± 11.3	1.7 ± 1.6	66.7 ± 11.5	3.8 ± 2.1	70.4 ± 12.5	0.0 ± 0.0	117.5 ± 24.0
		3.1-10 m	117.1 ± 14.9	169.6 ± 17.3	75.4 ± 10.2	12.5 ± 2.8	87.9 ± 10.4	9.2 ± 2.7	97.1 ± 9.0	0.0 ± 0.0	383.8 ± 31.1
		>10 m	130.0 ± 13.0	26.7 ± 7.1	18.3 ± 5.3	37.9 ± 5.0	56.3 ± 8.9	0.8 ± 0.8	57.1 ± 8.9	0.0 ± 0.0	213.8 ± 20.0
		Stumps & tops	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	526.3 ± 60.4	526.3 ± 60.4
		Total	247.1 ± 18.9	243.3 ± 25.3	158.8 ± 17.7	52.1 ± 5.9	210.8 ± 19.1	13.8 ± 4.0	224.6 ± 18.5	526.3 ± 60.4	1241.3 ± 100.2

* There were no trees in Tree Class E.

Table 30. Volume of "potential" logs in standing trees (Tree Class category A+B+D and undersized trees), by log grade and study block (mean ± SE).*

Study block	Diameter class	Length class	Log Grade or category								
			H+I+J (m^3/ha)	X+U (m^3/ha)	Y (≥80% sound) (m^3/ha)	Y (<80% sound) (m^3/ha)	Y (m^3/ha)	Z (m^3/ha)	Y+Z (m^3/ha)	Stumps & tops (m^3/ha)	Total (m^3/ha)
Mark-to-Leave	<30 cm	≤3 m	0.0 ± 0.0	0.6 ± 0.3	2.9 ± 0.4	0.0 ± 0.0	2.9 ± 0.4	0.0 ± 0.0	2.9 ± 0.4	0.0 ± 0.0	3.5 ± 0.5
		3.1-10 m	3.1 ± 1.3	19.1 ± 3.6	3.2 ± 0.6	2.2 ± 0.9	5.4 ± 1.0	0.0 ± 0.0	5.4 ± 1.0	0.0 ± 0.0	27.6 ± 4.7
		>10 m	14.8 ± 13.8	4.6 ± 4.2	4.6 ± 4.2	0.0 ± 0.0	4.6 ± 4.2	0.0 ± 0.0	4.6 ± 4.2	0.0 ± 0.0	23.8 ± 22.2
		Total	17.9 ± 13.5	24.2 ± 5.7	10.7 ± 4.3	2.2 ± 0.9	12.9 ± 4.2	0.0 ± 0.0	12.9 ± 4.2	0.0 ± 0.0	55.0 ± 22.4
	30-65 cm	≤3 m	0.0 ± 0.0	0.5 ± 0.5	7.1 ± 1.6	0.0 ± 0.0	7.1 ± 1.6	0.0 ± 0.0	7.1 ± 1.6	0.0 ± 0.0	7.6 ± 2.0
		3.1-10 m	30.2 ± 5.8	37.6 ± 8.5	12.3 ± 4.2	14.7 ± 3.7	27.0 ± 6.1	4.9 ± 2.4	32.0 ± 6.5	0.0 ± 0.0	99.7 ± 17.6
		>10 m	157.2 ± 17.4	16.1 ± 4.7	21.2 ± 5.0	2.3 ± 2.2	23.5 ± 5.2	0.0 ± 0.0	23.5 ± 5.2	0.0 ± 0.0	196.9 ± 17.5
		Total	187.5 ± 17.6	54.2 ± 11.1	40.6 ± 7.1	17.0 ± 3.5	57.6 ± 7.6	4.9 ± 2.4	62.6 ± 8.3	0.0 ± 0.0	304.2 ± 22.0
	>65 cm	≤3 m	0.0 ± 0.0	2.4 ± 1.5	3.0 ± 1.9	0.0 ± 0.0	3.0 ± 1.9	2.1 ± 2.0	5.1 ± 3.6	0.0 ± 0.0	7.5 ± 4.8
		3.1-10 m	102.1 ± 18.8	10.6 ± 5.3	0.0 ± 0.0	44.3 ± 14.3	44.3 ± 14.3	17.8 ± 9.3	62.1 ± 18.0	0.0 ± 0.0	174.8 ± 29.0
		>10 m	268.1 ± 36.1	40.7 ± 12.2	60.2 ± 31.2	135.4 ± 48.9	195.5 ± 57.9	11.9 ± 8.7	207.4 ± 56.4	0.0 ± 0.0	516.2 ± 77.3
		Total	370.2 ± 46.8	53.7 ± 13.8	63.1 ± 31.3	179.6 ± 46.7	242.8 ± 60.0	31.8 ± 14.3	274.6 ± 60.1	0.0 ± 0.0	698.4 ± 89.7
	Stumps & tops		0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	51.2 ± 4.5	51.2 ± 4.5
	Total	≤3 m	0.0 ± 0.0	3.5 ± 1.8	13.0 ± 2.6	0.0 ± 0.0	13.0 ± 2.6	2.1 ± 2.0	15.1 ± 4.1	0.0 ± 0.0	18.6 ± 5.7
		3.1-10 m	135.4 ± 18.2	67.3 ± 9.4	15.5 ± 4.3	61.2 ± 14.1	76.7 ± 16.5	22.7 ± 8.9	99.4 ± 19.2	0.0 ± 0.0	302.1 ± 30.1
		>10 m	440.1 ± 49.8	61.4 ± 12.5	85.9 ± 31.7	137.7 ± 48.6	223.6 ± 60.0	11.9 ± 8.7	235.5 ± 58.5	0.0 ± 0.0	736.9 ± 101.4
		Stumps & tops	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	51.2 ± 4.5	51.2 ± 4.5
		Total	575.5 ± 55.5	132.1 ± 15.6	114.4 ± 30.8	198.8 ± 46.2	313.3 ± 61.4	36.7 ± 14.6	350.0 ± 61.3	51.2 ± 4.5	1108.8 ± 112.6
Conventional	<30 cm	≤3 m	0.0 ± 0.0	1.8 ± 0.7	2.6 ± 0.7	0.2 ± 0.1	2.7 ± 0.7	0.0 ± 0.0	2.7 ± 0.7	0.0 ± 0.0	4.5 ± 1.2
		3.1-10 m	6.8 ± 2.6	17.1 ± 2.6	6.0 ± 1.2	0.5 ± 0.5	6.5 ± 1.1	0.0 ± 0.0	6.5 ± 1.1	0.0 ± 0.0	30.5 ± 3.5
		>10 m	24.4 ± 15.2	4.0 ± 3.2	0.0 ± 0.0	11.7 ± 8.2	11.7 ± 8.2	0.0 ± 0.0	11.7 ± 8.2	0.0 ± 0.0	40.1 ± 24.7
		Total	31.2 ± 15.3	23.0 ± 5.5	8.6 ± 1.3	12.3 ± 8.1	20.9 ± 8.7	0.0 ± 0.0	20.9 ± 8.7	0.0 ± 0.0	75.1 ± 26.1
	30-65 cm	≤3 m	0.0 ± 0.0	1.1 ± 0.7	4.5 ± 0.9	0.0 ± 0.0	4.5 ± 0.9	0.8 ± 0.5	5.3 ± 0.7	0.0 ± 0.0	6.4 ± 1.1
		3.1-10 m	47.7 ± 5.7	44.0 ± 7.5	19.3 ± 4.0	6.4 ± 2.6	25.7 ± 4.9	0.6 ± 0.6	26.3 ± 4.9	0.0 ± 0.0	118.1 ± 13.5
		>10 m	103.5 ± 12.1	27.2 ± 8.4	19.8 ± 6.3	9.3 ± 3.1	29.1 ± 6.3	0.0 ± 0.0	29.1 ± 6.3	0.0 ± 0.0	159.8 ± 16.8
		Total	151.3 ± 12.4	72.3 ± 10.6	43.6 ± 7.5	15.6 ± 3.8	59.3 ± 6.8	1.4 ± 1.0	60.7 ± 6.8	0.0 ± 0.0	284.3 ± 20.7
	>65 cm	≤3 m	0.0 ± 0.0	2.1 ± 1.5	2.0 ± 1.3	0.0 ± 0.0	2.0 ± 1.3	0.9 ± 0.9	2.9 ± 1.5	0.0 ± 0.0	5.0 ± 2.3
		3.1-10 m	74.3 ± 15.5	14.2 ± 5.1	6.0 ± 4.6	19.1 ± 8.3	25.1 ± 9.4	18.8 ± 7.0	43.9 ± 10.4	0.0 ± 0.0	132.4 ± 17.3
		>10 m	267.4 ± 45.0	23.3 ± 11.9	9.8 ± 5.4	236.1 ± 35.5	245.8 ± 36.4	5.6 ± 5.3	251.5 ± 35.8	0.0 ± 0.0	542.2 ± 75.8
		Total	341.7 ± 47.5	39.6 ± 16.2	17.7 ± 7.5	255.2 ± 36.3	272.9 ± 38.4	25.4 ± 7.9	298.3 ± 38.4	0.0 ± 0.0	679.6 ± 76.4
	Stumps & tops		0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	43.1 ± 8.4	43.1 ± 8.4
	Total	≤3 m	0.0 ± 0.0	5.0 ± 1.7	9.0 ± 1.5	0.2 ± 0.1	9.2 ± 1.5	1.7 ± 1.0	10.9 ± 2.0	0.0 ± 0.0	15.9 ± 2.8
		3.1-10 m	128.9 ± 15.1	75.4 ± 10.0	31.3 ± 6.4	26.0 ± 7.8	57.3 ± 10.5	19.4 ± 6.9	76.7 ± 10.3	0.0 ± 0.0	281.0 ± 25.6
		>10 m	395.3 ± 49.6	54.6 ± 15.6	29.6 ± 8.5	257.0 ± 34.6	286.6 ± 40.9	5.6 ± 5.3	292.2 ± 40.3	0.0 ± 0.0	742.1 ± 83.9
		Stumps & tops	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	43.1 ± 8.4	43.1 ± 8.4
		Total	524.2 ± 50.0	134.9 ± 21.9	69.9 ± 12.1	283.2 ± 33.3	353.1 ± 41.1	26.8 ± 7.7	379.8 ± 41.6	43.1 ± 8.4	1082.1 ± 91.4

* There were no trees in Tree Class E.

Table 31. Potential large low-value/non-merchantable pieces (diameter >65 cm; length >10 m) in Tree Classes A, B, and D: differences in density and volume, by study block (mean ± SE).

Study Block	Density (no. pieces/ha)	Volume (m^3/ha)
Mark-to-Leave	29.1 ± 7.2	207.4 ± 56.4
Conventional	30.8 ± 4.9	251.5 ± 35.8
Difference	- 3.3 ± 15.8	- 26.0 ± 108.2
p-value	*0.8354*	*0.8127*

tors influence not only the number of pre-harvest CWD pieces, but also the number of the timber-derived logs in Grades Y+Z combined that are retained, intact, in the setting following harvest.

Whether the pre-harvest CWD pieces are left intact depends on such factors as merchantability, harvesting method, and state of decay. Except in the case of safety, merchantable CWD pieces are generally utilized to avoid billing. The relative proportion of merchantable to non-merchantable wood is governed by site factors, such as stand age, edatopic conditions, and local mortality agents. For the pilot site, the majority of the CWD pieces were low-value (Y Grade) or non-merchantable (Z Grade), and ranged from Moderately Decayed to Well Decayed. The literature reports breakage and crushing as a major harvesting-related hazard for these softer, decomposed pieces (McCarthy and Bailey 1993; Gore and Patterson 1985; Davis et al. 2001). Moderately Decayed to Well Decayed pieces were often broken up or crushed due to falling trees; machine traffic; yarding (i.e., picking-up and dropping of pieces that appear to be merchantable); or dragging pieces when yarding deflection was low.

Similarly, various factors influence how many of the potential low-value/non-merchantable pieces (Y+Z) in the standing timber are retained in the setting. The pulp market is a major influencing factor in terms of the utilization of low-grade wood in the timber, e.g., Y Grade logs. On the pilot site, the Y Grade logs in the timber represented approximately 18% of the total cruise value. In low market conditions, such as in 2000/2001, Y Grade logs will be left in the setting; however, these logs will likely be utilized with improved market conditions. Other factors that determine how many low-value/non-merchantable logs are yarded to roadside or loaded off site include:

- species susceptibility to shattering (e.g., western redcedar) – shattering will affect the dimensions, not only of the recoverable wood, but also of the non-merchantable wood (Ruth and Harris 1975);
- inability to visually assess merchantability until the log is yarded to roadside;
- concern that the operation will be penalized for leaving merchantable logs on the setting; bucking to preferred log lengths; or lack of training (Phillips 2001).

Many of the latter risk factors can be minimized, but not eliminated, by the modified bucking and yarding practices used in the Mark-to-Leave Block. Comparing the two blocks will provide an opportunity to evaluate the effects of the two bucking and yarding practices on volume and piece dimensions, and will serve to highlight difficulties in implementing these practices on an operational scale.

8.2 Block Comparisons

The total gross volumes of low-value and non-merchantable wood in the timber and CWD combined were not significantly different between the two blocks. However, there were a few significant differences between the blocks in the distribution of this wood, which may or may not confound the detection of post-harvest differences. The high within-block variability of most, although not all, compiled strata, undoubtedly obscured the detection of other differences between blocks.

The main significant difference detected between the blocks is the total CWD volume/ha. The significantly higher total CWD volume/ha for the Mark-to-Leave Block reflects a noticeably higher density of larger sized pieces. In addition, there is a significant difference in the distribution of pieces by decay class between the blocks. The Conventional Block has a higher proportion of smaller pieces in the Well-Decayed Classes, while the Mark-to-Leave Block has a higher proportion of larger pieces in the Moderately to Well-Decayed Classes.

Because CWD represents approximately one-third of the total "potential" low-value/non-merchantable wood volume on site, the effect of these differences on the retention of CWD after harvest is unclear. If the large CWD pieces are displaced and/or crushed during harvesting (i.e., do not contribute to the post-harvest CWD), then the pre-harvest differences can be ignored when making post-harvest comparisons. On the other hand, if the large CWD pieces are undisturbed, then the pre-harvest differences will account for a greater or lesser proportion of the post-harvest differences, depending on whether the input of low-value logs from the standing timber is large or small. In any event, the pre-harvest differences will be accounted for in part by comparing the change in total "potential" low-value/non-merchantable wood after harvesting for both blocks. The large pieces are of particular importance because there is an influx of small-diameter pieces and a possible loss of larger pieces after harvesting (McCarthy and Bailey 1993; Pong and Henley 1973; Gore and Patterson 1985).

8.3 Literature Comparisons for Dead Wood

8.3.1 Total Volume/ha

Total CWD volumes reported in the literature for the CWHvm subzone variants, or related ecosystems, vary. **Table 32** provides examples from the sparse literature. Research by Spies et al. (1988) in the Cascade Mountains in Washington State is included, even though Douglas-fir is the dominant species in these stands, because these forests have ages that are comparable to many stands in the CWHvm subzone variant (i.e., >350

years), and because Douglas-fir, like western redcedar and cypress, are decay resistant. [It is noted that comparisons between different inventories must be done cautiously because of differences in definitions: e.g., decay classification, minimum diameter, volume functions, and sampling methods (Fridman and Walheim 2000).]

The total pre-harvest volume/ha of CWD (216 m^3/ha) in this study is noticeably less than several values reported in the literature for old-growth stands in the CWHvm subzone variant, but is within the general range reported by Inselberg (1993) and by Beese and Toms (1995). It is anticipated that the observed between-study variation in total CWD volume reflects stand-to-stand differences in such factors as:

1. Species composition: Stand composition influences the size of dead-wood pieces because species differ in longevity and maximum potential size (i.e., diameter and height) (Franklin and Warring 1980). Further, species differ in their susceptibility to decay. Western redcedar, cypress, and Douglas-fir are decay resistant, therefore CWD may persist for centuries. In contrast, species such as western hemlock and balsam are more susceptible to decay (Graham 1982, as cited on page 1701 in Spies et al. 1988). Spies et al. (1988) surmise that stands dominated by western hemlock tend to have lower peak total dead wood biomass levels in an old-growth stage than will stands dominated by Douglas-fir in an old-growth stage.

2. Site productivity: The growing potential of a site, i.e., soil moisture and/or nutrient regimes, directly influences the size of live trees and indirectly influences the size and volume of dead wood (Ruth and Harris 1975). Harmon et al. (1986) refer to this positive relationship between total dead wood production and living biomass (cited on page 605 in Harmon and Chen 1991). For virgin pine and spruce stands

Table 32. Examples of total, old-growth, dead-wood volumes reported in the literature.

Literature cited	Ecosystem	Sites (no.)	Plots (no.)	Volume			Species composition/ productivity
				Mean total CWD (m^3/ha)	Mean total snags (m^3/ha)	Mean total dead wood (m^3/ha)	
Beese and Toms 1996	CWHvm1	2	1	142 to 547	Stems/ha only	n.a.	CwHw
Beese and Toms 1996	CWHvm2	2	1	155 to 449	Stems/ha only	n.a.	CwHwBa
Wells and Trofymow 1997	CWHvm	4	1	650 ± 121	n.a.	n.a.	
Inselberg 1993	CWHvm1				Stems/ha only	n.a.	n.a.
	Low productivity	8	1	~85 [a]			
	Med. productivity	11	1	~420			
	High productivity	15	1	~350			
Inselberg 1993	CWHvm2				Stems/ha only	n.a.	n.a.
	Low productivity	5	1	~390			
	Med. productivity	2	1	~260			
Huggard 2000	CWHvm Remnant patch	2	1	~690 to 700	Stems/ha only	n.a.	CwHwFd
Spies et al. 1998	Western hemlock/ Pacific silver fir zones: Washington Cascades	24	5	319 ± 23	227 ± 25	544 ± 36	FdHw

[a] Estimates from graphs.

in Sweden, Linder et al. (1997) report a strong relationship between total stem volume (live and dead trees) and site productivity (m^3/ha/y). However, they found no detectable relationship between the volume of dead trees (standing and fallen) and site quality. In old-growth Coastal Douglas Fir stands in the United States, Spies et al. (1988) report a positive relationship between total dead-wood volume and moisture class. For old-growth stands in the Coastal Western Hemlock biogeoclimatic zone of British Columbia, Inselberg (1993) also reports a positive relationship between total CWD volume and medium-to-high site productivity (i.e., soil moisture/nutrient regimes).

3. Succession stage: For a given subzone variant, the duration of the old-growth successional stage can vary, thus reflecting the above factors and local disturbance agents. Research suggests that the older stands will tend to have the higher total dead-wood volumes (Spies et al. 1988; Wells et al. 1988). Based on models for Douglas-fir stands, total dead wood accumulates well into late succession until perhaps a steady state is reached 1200–1500 years after stand establishment. Spies et al. (1988) indicate that a steady state would probably not be achieved if a major disturbance occurred. In the CWHvm2 subzone variant, the projected return interval for catastrophic disturbances is >250 years (BCMOF 1995). However, ages for some individual trees for this subzone variant are reported to be well beyond 450 years (Beese and Toms 1995).

4. Dominant mortality agent (e.g., wind versus insects): The intensity and frequency of local mortality agents influences both the size and density of dead trees, and whether these trees are standing or down.

Collectively, the above factors govern total dead-wood volume and its associated attributes, as well as the proportion of dead wood that is on the ground. As a result, it is not surprising that a poor relationship exists between standing or suspended and down material (Harmon and Sexton 1996). Harmon and Sexton state that "even within a single forest type, it is not unusual to find that this proportion varies widely; snags can make up as little as 2% or as much as 98% of the dead wood biomass". For old-growth stands in Sweden, Fridman and Walheim (2000) report a wide range in the ratio of snag-to-CWD volumes across six vegetation zones. In the absence of a large data set, total dead-wood volume may be a more stable index for interpretation than CWD alone.

In this study, the total dead-wood volumes in the blocks were not significantly different, representing 23 to 29% of the total site volume. However, the total CWD volumes in the blocks were significantly different.

8.3.2 CWD Piece Attributes

Much of the available information about the attributes of CWD for comparable ecosystems is limited to volume/ha by diameter class or decay class. More recent research on CWD attributes in other ecosystems has started to focus on other attributes such as piece density and length (e.g., Torgersen and Bull 1995) and percent cover (e.g., Carey and Johnson 1995). This extra information provides key habitat information for a range of species, for instance, black bears (Davis 1996), pileated woodpeckers (Hartwig 1999), and carpenter ants (Torgersen and Bull 1995). This additional information is also required for comparisons to various American federal CWD guidelines which refer to number of pieces/ha by diameter and length classes (PNW 1995; USDA 1994). Studies that document this information have, to date, been conducted in only the drier ecosystems.

In this study, the large-diameter pieces represent a small proportion of the total number of CWD pieces (~10%), but represent a large portion of the total CWD volume (~60%). For logs with a large-end diameter >60 cm, Spies et al. (1988) report a mean density of 66 pieces/ha. In the Mark-to-Leave Block, the mean density for CWD pieces with a large-end diameter >65 cm is 66 pieces/ha; 32 pieces/ha have a piece length >10 m. Wells and Trofymow (1997) report logs with a transect diameter >60 cm represent over 50% of the total CWD volume/ha for old-growth stands in the CWHvm subzone variant. Large pieces are of particular importance for CWD management because these are the pieces at most risk for removal or break-up during harvesting. Typically, harvesting results in an increase in the smaller pieces, due in part to utilization size limits, e.g., 3-m logs and 10-cm tops (Davis et al. 2001; Ruth and Harris 1975; Spies et al. 1988).

In this study, the majority of CWD volume/ha is split equally between the Moderate and High Decay Classes. For old-growth stands, Spies et al. (1988) and Wells and Trofymow (1997) similarly report most of the CWD volume/ha in Decay Classes 3 and greater. The relative proportions between the Moderately Decayed and Well-Decayed Classes vary slightly, but in both these studies the higher decay classes (Decay Classes 4 and 5) represent over 30% of the total volume. Differences in volume distribution by decay class likely reflect differences in the decay rates of different species.

8.4 Post-Harvest Surveys

Upon completion of the primary harvesting (e.g., early June 2001), the two blocks will be inspected to determine whether the distribution of CWD is relatively uniform throughout the harvesting site stratum. Based on a preliminary walk-though in November 2000, it is anticipated that five strata will be sampled:

1. Roadside: 15-m width on either side of road.
2. Fall-out zone: 10 m adjacent to the roadside stratum on the down-slope side of the road.
3. Knoll shadow: on the Mark-to-Leave Block.
4. Debris piles in the excavator-forwarded areas.
5. Remainder of the dispersed stratum.

Plots that were sampled prior to harvesting will be re-established, classified as to strata, and sampled. Additional plots, or a minimum of three plots per new stratum, whichever is larger, will be established to provide representation by area.

8.5 Towards the Development of Quantitative CWD Management Guidelines: Future Survey Needs

In addition to providing a comparison between bucking and yarding practices, an underlying objective of this study was to contribute stand-level information to a database that will be used to evaluate the need for establishing targets for CWD retention. The study provides intensive pre- and post-harvest data for an old-growth stand in the CWHvm2 subzone variant with high decay and waste.

A full pre-harvest inventory, such as used in this study, provides an opportunity to relate one ecosystem component to another (Harmon and Sexton 1996). A variety of current and hypothetical questions can therefore be posed.

1. What proportion of the total stand volume is represented by dead wood?

2. What proportion of the total dead wood is down?

3. What proportions of the total stand volume or total dead-wood volume are represented by proposed CWD targets?

4. What are the dimensions of a large CWD piece?

5. What is the density of a large CWD piece?

6. Are the diameters of live and dead stems sufficiently large to provide for large CWD pieces?

The timber net factoring call grading[27] included in this study also permits exploration of merchantability questions such as:

1. What is the total, "potential", low-value wood available on site, i.e., in terms of CWD, standing timber?

2. How much of the original CWD is merchantable?

3. Is there sufficient "potential" low-value/non-merchantable wood to meet proposed CWD targets? If not, what are the management strategies?

The post-harvest inventory permits an evaluation of such questions as:

1. Under different harvesting systems (e.g., clearcut, variable retention, single-tree selection):

   • What proportion of the total, "potential", low-value/non-merchantable wood was retained as CWD or standing trees in the setting, at roadside, and in reserves?

   • What are the dimensions of the CWD pieces retained in the setting, at roadside, and in reserves?

   • How much of the pre-harvest CWD was left intact in the setting, roadside, and reserves?

2. What proportion of the post-harvest CWD volume is benchmark?

3. What is the ratio of post-harvest CWD to pre-harvest total dead wood volume/ha?

This study was designed to address a broad range of questions. Detailed projects, such as this study, which involve intensive pre- and post-harvest monitoring of different options for managing CWD, are expensive and time consuming. However, a limited number of these types of projects are required to integrate issues related to forestry, economics, ecology, and operations. The integrated study provides baseline data, but more importantly it provides the data required to "troubleshoot" potential management issues during the developmental rather than the implementation stage of CWD management guidelines: i.e., do the proposed target volumes exceed the total low-value/non-merchantable wood volumes; which operational tools are cost-effective and where?

The intensive project, however, is too costly and time consuming to provide the broad database required for developing targets for CWD management. A more cost-effective approach of collecting stand data over a broad range of sites, and within a relatively short time frame, is required to establish a sufficiently large database. Current operational surveys (i.e., residue survey, operational cruise) provide only a portion of the required stand data. Research data, while often complete, are limited in scope. The alternative to collecting data through an independent survey, which will be costly, is to append the collection of the "missing" CWD data to an existing operational survey. Because CWD attributes are closely tied to those of standing live and dead trees, and there is some overlap in data collection, e.g., windfalls, the logical choice is to collect the required CWD measurements at the time of the operational cruise. This "modified" operational cruise might apply to all or only a subset of the total plots. The feasibility of this approach is currently under investigation by members of the Vancouver Forest Region's CWD Working Group (TWIFPPSC 2001).

For Coastal old-growth stands, in particular, it will be advantageous for the operational cruise to include net factoring call grading because: 1) low-value/non-merchantable wood is present in both live and dead trees, and 2) net factoring call grading generally provides a more accurate estimate of merchantability and log dimensions than the BCMOF's appraisal cruising procedures[28]. In the short-term, the operational cruise should provide an inventory of all dead trees and CWD volumes and attributes. Until the database is sufficiently large, "total dead wood" may be a useful management index of dead wood, owing to the variable nature of CWD alone.

Any future database will require stratification by factors that influence dead-wood attributes. Preliminary summary strata may include: stand age (e.g., young, mature, old-growth), natural disturbance regime, dominant species, and site productivity group-

[27] Call grading and net factoring are processes used to assess timber quality and net tree volume. They are applied to the tree as the cruiser sees it. No attempt is made to predict grade based on falling breakage or any manufacturing process, or to predict volume loss without direct evidence (e.g., Vegetation Resources Inventory).

[28] See Footnote 6.

ings (e.g., L and M+H based on the BC Ministry of Forest's *Site Index Estimates by Site Series for Coniferous Tree Species in British Columbia* (BCMOF 1997)). An approach such as this will reduce the total number of strata by groupings that can be related back to biogeoclimatic classification, i.e., subzone variants, moisture groupings. **Table 33** is an example of a pre-harvest site summary table; **Table 34** is an example of a pre-harvest CWD summary table. **Table 35** is an example of a post-harvest CWD summary table for the dispersed stratum. Similar summaries for other post-harvest strata (e.g., roadside, piles) will also be of interest. Once the database is sufficiently large, however, analyses such as misclassification matrix, discriminate or cluster analyses should be used to evaluate the efficacy of the original and to suggest alternative summary strata.

Last, the future development of quantitative CWD management guidelines will require the integration of multiple sources of information, e.g., landscape management objectives, wildlife habitat research, operational issues, stand development models. The availability of a database that provides pre- and post-harvest information on all main stand structures and strata (e.g., roadside, Wildlife Tree Patches), will be valuable to the developmental process, as it will provide insight into the implications (i.e., economic, ecological) of future retention targets, and provide data to evaluate options for integrating, on a quantitative basis, CWD objectives with those for Wildlife Tree Patches and other reserves (e.g., Riparian Management Zones).

Table 33. Total pre-harvest dead-wood volume, partitioned by structures (s) and merchantability: Example Coastal Summary Table (mean, SE, *n*).

NDT and broad age groupings	Broad timber types	Productivity class	Corresponding biogeoclimatic subzone variants / moisture / nutrient groupings	Total stand volume [a] (m^3/ha)	Total dead-wood volume [b] (m^3/ha)	Total CWD volume (m^3/ha)	Total dead standing (m^3/ha)	Total stump volume [c] (m^3/ha)	Total site volume of Y+Z wood (m^3/ha)	Volume of Y+Z wood in live trees (Tree Class A) (m^3/ha)	Volume of Y+Z wood in dead standing trees (Tree Classes B+D) (m^3/ha)	Volume of Y+Z wood in CWD (other + Tree Classes C+E) (m^3/ha)
Old growth or second growth	Fd	H+M	e.g., CDFmm01,03									
		L										
	FdHw	H+M										
		L										
	FdPl	H+M										
		L										
	Cw/Cy	H+M										
		L										
	CwFd	H+M										
		L										
NDT 1 or NDT 2	CwS	H+L										
		L										
	CwHw	H+M										
		L										
	Hw	H+M										
		L										
	HwCw	H+M										
		L										
	HwFd	H+M										
		L										
	HwBa	H+M										
		L										
	HwPl	H+M										
		L										
	Pl	H+M										
		L										
	PlYc	H+M										
		L										
	S	H+M										
		L										
	SHm	H+M										
		L										
EXAMPLE from Mark-to-Leave Block												
Old Growth	HwBa	UA106D3F	CWHvm2 01 mean	1334	346	216	105	25	599	269	97	210
NDT 1		(23 plots)	N=1 SE	81	34	25	16	3	47	29	15	25

[a] Total stand volume includes live and dead standing, CWD, and stumps. [b] Total dead-wood volume includes standing dead trees (bole, stump, and top), CWD (Tree Classes C+E and "other"), and stumps (short snags <3 m in height). [c] **Stump refers to a short dead snag <3 m in height.**

Table 34. Pre-harvest attributes and potential sources of large CWD (other + Tree Classes C+E): Example Coastal Summary Table (mean, SE, *n*).

NDT and broad age groupings	Broad timber types	Productivity class	Corresponding biogeoclimatic subzone variants / moisture / nutrient groupings	Large-end diam. of large CWD pieces[a] (cm)	Length of large CWD pieces[a] (m)	Total density of pre-harvest large CWD pieces[b] (no./ha)	Total volume of pre-harvest large CWD pieces[b] (m^3/ha)	Total density of pre-harvest large CWD pieces[b] in Grades Y+Z (no./ha)	Total volume of pre-harvest large CWD pieces[b] in Grades Y+Z (m^3/ha)	Total density of large Y+Z Grade pieces[b] in standing timber (Tree Classes A+B+D) (no./ha)	Total volume of large Y+Z Grade pieces[b] in standing timber (Tree Classes A+B+D) (m^3/ha)
Old growth or second growth	Fd	H+M	e.g., CDFmm01,03								
		L									
	FdHw	H+M									
		L									
	FdPl	H+M									
		L									
	CwCy	H+M									
		L									
	CwFd	H+M									
		L									
NDT 1 or NDT 2	CwS	H+L									
	CwHw	H+M									
		L									
	Hw	H+M									
		L									
	HwCw	H+M									
		L									
	HwFd	H+M									
		L									
	HwBa	H+M									
		L									
	HwPl	H+M									
		L									
	Pl	H+M									
		L									
	PlYc	H+M									
		L									
	S	H+M									
		L									
	SHm	H+M									
		L									
EXAMPLE from Mark-to-Leave Block											
Old Growth	HwBa	UA106D3F	CWHvm2 01 mean	65[c]	10[c]	22	99	21	94	30	230
NDT 1		(23 plots)	N=1 SE	na	na	3	18	3	17	4	32

[a] Defined as the upper 5 or 10% of the length and diameter cumulative distribution frequency. [b] All pieces meeting both the large diameter and length criteria.
[c] In the current study, CWD pieces that exceed the criteria for large pieces have a mean large-end diameter (cm) of 88 (2.6) and a mean length (m) of 21 (0.7).

Table 35. Post-harvest CWD attributes for the dispersed stratum: Example Coastal Summary Table (mean, SE, *n*).

NDT and broad age groupings	Broad timber types	Productivity class	Corresponding biogeoclimatic subzone variants / moisture / nutrient groupings	Large-end diam. of large CWD pieces[a] (cm)	Length of large CWD pieces[a] (m)	Total CWD volume (m^3/ha)	Total density of large CWD pieces[b] (no./ha)	Total volume of large CWD pieces[b] (m^3/ha)	Total avoidable waste benchmark volume (m^3/ha)	Total density of large CWD pieces classed as avoidable waste[b] (no./ha)	Total volume of large CWD pieces classed as avoidable waste[b] (m^3/ha)	Ratio of mean pre-harvest total CWD/ mean post-harvest CWD volume/ha
Old growth or second growth	Fd	H+M	e.g., CDFmm01,03									
		L										
	FdHw	H+M										
		L										
	FdPl	H+M										
		L										
	Cw/Cy	H+M										
		L										
	CwFd	H+M										
		L										
NDT 1 or NDT 2	CwS	H+L										
		L										
	CwHw	H+M										
		L										
	Hw	H+M										
		L										
	HwCw	H+M										
		L										
	HwFd	H+M										
		L										
	HwBa	H+M										
		L										
	HwPl	H+M										
		L										
	Pl	H+M										
		L										
	PlYc	H+M										
		L										
	S	H+M										
		L										
	SHm	H+M										
		L										

[a] Defined as the upper 5 or 10% of the length and diameter cumulative distribution frequency.

[b] All pieces meeting both the large diameter and length criteria.

9 LITERATURE CITED

Angelstam, P. 1997. "Landscape Analysis as a Tool for the Scientific Management of Biodiversity" in *Ecology Bulletin* 46:140-170.

BC Ministry of Forests. 1997. *Ministry Policy Manual. Volume 1, Resource Management. Chapter 8, Tenure Administration. Policy 8.1, Timber Utilization—Coastal and Interior.* Resource Tenures and Engineering Branch. Victoria, BC.

BC Ministry of Forests. 1999. *Scaling Manual.* Revenue Branch. Victoria, BC.

———. 2000a. *Logging Residue and Waste Procedures Manual.* Revenue Branch. Victoria, BC.

———. 2000b. *Cruising Manual.* Revenue Branch. Victoria, BC.

———. 2000c. *Vegetation Resources Inventory—Ground Sampling Procedures.* Resources Inventory Branch. Victoria, BC. 313p.

———. 2000d. *A Short-Term Strategy for Coarse Woody Debris Management in British Columbia's Forests, March 2000.* Victoria, BC.

BC Ministry of Forests and BC Ministry of Environment, Lands and Parks. 1995. *Biodiversity Guidebook.* September 1995. Forest Practices Branch, BC Ministry of Forests. Victoria, BC. Forest Practices Code of British Columbia Guidebook. 99p.

———. 1996. *Forest Practices Code Timber Supply Analysis.* Forest Practices Branch, BC Ministry of Forests. Victoria, BC. 33p.

———. 1999. *Landscape Unit Planning Guide.* Forest Practices Branch, BC Ministry of Forests. Victoria, BC. Forest Practices Code of British Columbia Guidebook. 101p.

Beese, W.J. and J. Toms. 1995. *Age Structure and Stand Dynamics of Old-Growth Forests on Vancouver Island.* Internal report prepared for Land Use Planning Advisory Team, Corporate Forestry, MacMillan Bloedel Limited. Nanaimo, BC. 34 p.

Bull, E.L. and R.S. Holthausen. 1993. "Habitat Use and Management of Pileated Woodpeckers in Northeastern Oregon" in *Journal of Wildlife Management* 57(2):335–345.

Bull, E.L.; C.G. Parks; and T.R. Torgersen. 1997. *Trees and Logs Important to Wildlife in the Interior Columbia River Basin.* Pacific Northwest Research Station, Forest Service, USDA. General Technical Report 391. 55p.

Carey, A.B.; C. Elliott; B.R. Lippke; J. Sessions; C.J. Chambers; C.D. Oliver; J. F. Franklin; and M.G. Raphael. 1996. *Washington Forest Landscape Management Project: A Pragmatic Ecological Approach to Small-Landscape Management.* Washington State Department of Natural Resources; and Pacific Northwest Research Station, Forest Service, USDA. Washington Forest Landscape Management Project Report No. 2.

Carey, A.B. and M.L. Johnson. 1995. "Small Mammals in Managed, Naturally Young and Old Growth Forests" in *Ecological Applications* 5(2): 336-352.

Caza, C.L. 1993. *Woody Debris in the Forests of British Columbia: A Review of Literature and Current Research.* Research Branch, BC Ministry of Forests, Victoria. Land Management Report 78. 99p.

Davis, G.; A. Nemec, and E. Redlin. 2001, in preparation. *Pre- and Post-Harvest Attributes of Coarse Woody Debris in Unmanaged Forests: Case Studies in Coastal Western Hemlock Wet Hypermaritime Biogeoclimatic Subzone.* Vancouver Forest Region Forest, BC Ministry of Forests. Nanaimo, BC. Technical Report TR-0xx.

Davis, G.; E. Phillips; and B. Cawley. 2000. *Maintaining Coarse Woody Debris in Post-Harvest Settings: Economic and Ecological Implications of Marking Non-Merchantable Logs after Bucking and Before Yarding—Project Plan.* Vancouver Forest Region Forest, BC Ministry of Forests. Nanaimo, BC. Internal document. VFR-CWD-00-01.

Davis, H. 1996. *Characteristics and Selection of Winter Dens by Black Bears in Coastal British Columbia.* M.Sc. thesis, Simon Fraser University. Burnaby, BC. 147p.

Forrester, P.D. 1996. *Fibre Recovery from Log Sortyard Residues on Coastal British Columbia.* Western Division, FERIC. Vancouver, BC. Technical Note TN-249. 16p.

Franklin, J.F. and R.H. Waring. 1980. "Distinctive Features of the Northwestern Coniferous Forest: Development, Structure and Function" pp. 59–85 in *Forests: Fresh Perspectives from Ecosystem Analysis.* Proceedings of the 40th Annual Biology Colloquium. Oregon State University Press. Corvallis, Oregon.

Fridman, J. and M. Walheim. 2000. "Amount, Structure and Dynamics of Dead Wood on Managed Forestland in Sweden" in *Forest Ecology and Management* 131 (1/3): 23–36.

Goodburn, J.M. and C.G. Lorimer. 1998. "Cavity Trees and Coarse Woody Debris in Old-Growth and Managed Northern Hardwood Forests in Wisconsin and Michigan" in *Canadian Journal Forest Research* 28:427–438.

Gore, J.A. and W.A. Patterson III. 1985. "Mass of Downed Wood in Northern Hardwood Forests in New Hampshire: Potential Effects of Forest Management" in *Canadian Journal Forest Research* 16:335–339.

Green, P. and G.F. Peterken. 1997. "Variation in the Amount of Dead Wood in the Woodlands of the Lower Wye Valley, UK in Relation to the Intensity of Management" in *Forest Ecology and Management* 98:229–238.

Hansen, A.J.; T.A. Spies; F.J. Swanson; and J.L. Ohmann. 1991. "Conserving Biodiversity in Managed Forests: Lessons from Natural Forests" in *BioScience* 41(6):382–392.

Harmon, M.E. and H. Chen. 1991. "Coarse Woody Debris Dynamics in Two Old Growth Ecosystems" in *Bioscience* 41(9):604–610.

Harmon, M.E.; J.F. Franklin; F.J. Swanson; P. Sollins; S.V. Gregory; J.D. Lattin; N.H. Anderson; S.P. Cline; N.G. Aumen; J.R. Sedell; G.W. Lienkaemper; K. Cromack Jr.; and K.W. Cummins. 1986. "Ecology of Coarse Woody Debris in Temperate Ecosystems" in *Advances in Ecological Research* 15:133–302.

Harmon, M.E. and J. Sexton. 1996. *Guidelines for Measurements of Woody Detritus in Forest Ecosystems.* US LTER Network Office: University of Washington. Seattle, WA. Publication No. 20. 73p.

Hartwig, C.L. 1999. *Effect of Forest Age, Structural Elements, and Prey Density on the Relative Abundance of Pileated Woodpecker (Dryocopus pileatus abieticola) on South-Eastern Vancouver Island.* M.Sc. thesis, University of Victoria. Victoria, BC. 163p.

Howard, J.O. 1975. *Logging Residues – Volume and Characteristics.* Forest Service, USDA. Forest Service Resource Bulletin PNW-44. (cited in Nagle 1980)

Huggard, D. 2000. *Weyerhaeuser BC Variable Retention Adaptive Management Program: Habitat Monitoring 1999— Summary and Sample Design Analysis.* Weyerhaeuser, BC Coastal Group. Nanaimo, BC. Internal document, January 2000. 57p.

Inselberg, A.E. 1993. *A Survey of the Composition and Structure of Forest Ecosystems in the Tofino Creek Watershed on Vancouver Island.* Research Program, BC Ministry of Forests. Victoria, BC. 285p.

Keenan, R. and A. Inselberg. In press. Coarse woody debris in a forested watershed on the west coast of Vancouver Island, British Columbia.

Kozak, A. 1988. "A Variable-Exponent Taper Equation" in *Canadian Journal Forest Research* 18:1363–1368.

Per Linder; B. Elfving; and O. Zackrisson. "Stand structure and successional trends in virgin boreal forest reserves in Sweden" in Forest Ecology and Management 98 (1997):17–33.

Lloyd, R. 2001. *A Comparison of Coarse Woody Debris in Harvested and Unharvested Sites in the SBSmc2, First-Year Report.* Houston Forest Products Ltd. Houston, BC. 15p.

Maser, C. and J.M. Trappe (editors). 1984. *The Seen and Unseen World of the Fallen Tree.* Pacific Northwest Research Station, Forest Service, USDA. Portland, Oregon. General Technical Report PNW-GTR-164. 56p.

McCarthy, B. and R. Bailey 1993. "Distribution and Abundance of Coarse Woody Debris in a Managed Forest Landscape of the Central Appalachians" in *Canadian Journal Forest Research* 24:1317–1329.

Nagle, G.S. 1980. *Analysis of Salvage Yarding Systems and Costs in Pacific Coast Forests.* ENFOR, Canadian Forestry Service; Dept. of Environment. Ottawa, Ontario. BC-X-214.

Pacific Northwest Research Station. 1995. *Decision Notice for the Revised Continuation of Interim Management Direction Establishing Riparian, Ecosystem and Wildlife Standards for Timber Sales.* Forest Service, USDA. Portland, Oregon. 13p. (cited in Bull et al. 1997)

Parks, C.G.; E.L. Bull; and T.R. Torgersen. 1997. *Field Guide for the Identification of Snags and Logs in the Interior Columbia River Basin.* Pacific Northwest Research Station, Forest Service, USDA. General Technical Report PNW-GTR-390. 40p.

Phillips, E. 2001. *A Trial to Determine the Economics of Coarse Woody Debris Retention During Harvesting of Coastal Old-Growth.* March 2001—Progress Report. Western Division, FERIC. Vancouver, BC. 16p.

Pong, W.Y. and J.W. Henley. 1978. *Characteristics of Residues in a Helicopter Logged Area of Old-Growth Douglas-Fir.* Pacific Northwest Forest and Range Experiment Station, Forest Service, USDA. Research Note PNW-320. 32p.

Province of British Columbia. *Forest Practices Code of BC Act. Operational Planning Regulation (OPR). Part 3—Forest Development Plans. Division 3—Map and Information Requirements for all Forest Development Plans. Sec 18(1)(n).* Victoria, BC.

———. *Forest Practices Code of BC Act. Operational Planning Regulation (OPR). Part 5—Silviculture Prescriptions. Division 1—Scope and Content. Sec 39(3)(m).* Victoria, BC.

Reid, C.M.; A. Foggo; and M. Speight. 1996. "Dead Wood in the Caledonia Pine Forest" in *Forestry* 69(3): 275–279.

Ruth, R.H and A.S. Harris. 1975. *Forest Residues in Hemlock-Spruce Forests of the Pacific Northwest and Alaska—A State-of-Knowledge Review with Recommendations for Residue Management.* Forest Service, USDA. Portland, Oregon. General Technical Report PNW-39. 52p.

Samuelsson, J.; L. Gustafsson; T. Ingelog. 1994. *Dying and Dead Trees: A Review of Their Importance for Biodiversity.* Swedish Threatened Species Unit. Uppsala, Sweden. Swedish Environmental Protection Agency report series, Report 4306.

Site Productivity Working Group (SPWG). 1997. *Site Index Estimates by Site Series for Coniferous Tree Species in British Columbia.* BC Ministry of Forests and Forest Renewal BC. Victoria, BC. 265p.

Spies, T.A. and S.P. Cline. 1988. "Coarse Woody Debris in Forests and Plantations of Coastal Oregon" pp.5–24 in *From the Forest to the Sea: A Story of Fallen Trees.* Technical editors C. Maser, R.F. Tarrant, J.M. Trappe, J.F. Franklin. Pacific Northwest Research Station, Forest Service, USDA. Portland, Oregon. General Technical Report PNW-GTR-229. 153p.

Spies, T.A. and J.F. Franklin. 1988. "Old Growth and Forest Dynamics in the Douglas-Fir Region of Western Oregon and Washington" in *Natural Areas Journal* 8(3):190–201.

Spies, T.A.; J.F. Franklin; and T.B. Thomas. 1988. "Coarse Woody Debris in Douglas-Fir Forests of Western Oregon and Washington" in *Ecology* 69:1689–1702.

Stone, J.N.; A. MacKinnon; and J. Parminter. 1998. "Coarse Woody Debris Decomposition Documented Over 65 Years on Southern Vancouver Island" in *Canadian Journal of Forest Research* 28:788–793.

Timber West/International Forest Products Project Subcommittee (TWIFPPSC). 2001. *Validation of a Modified Operational Cruise Designed to Sample Dead Wood, Interim Working Document, Version 1.* Vancouver Forest Region, BCMOF. Nanaimo, BC. http://www.for.gov.bc.ca/vancouvr/research/cwd/cwdvalidation.pdf

Torgersen, T.R. In press. "Characteristics of Log Resources in Northeastern Oregon—Case Studies of Four Management Treatments" pp. xx-xx in *Proceedings of Ecology and Management of Dead Wood in Western Forests, November 2–4 1999, Reno, Nevada.* Pacific Southwest Research Station, Forest Service, USDA. Fresno, CA. General Technical Report PSW-GTR-xxx-xxx.

Torgersen, T.R. and E.L. Bull. 1995. "Down Logs as Habitat for Forest-Dwelling Ants—the Primary Prey of Pileated Woodpeckers in Northeastern Oregon" in *Northwest Science* 69 (4): 294–303.

USDA Forest Service; and US Department of the Interior, Bureau of Land Management. 1994. Record of Decision: For amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl: Standards and Guidelines: For management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. [Northwest Forest Plan]. Portland, OR.

Wells, R.W.; K.P. Lertzman; and S.C. Saunders. 1998. "Old-Growth Definitions for the Forests of British Columbia, Canada" in *Natural Areas Journal* 18:279–292.

Wells, R.W. and J.A. Trofymow. 1997. *Coarse Woody Debris on Chronosequences in Coastal Forests of British Columbia.* Pacific Forestry Centre, Canadian Forest Service. Victoria, BC. Internal document. 42p.

Wildlife Tree Committee of British Columbia. 1994. *Wildlife/Danger Tree Assessor's Course Workbook.* 2nd Edition. Editors Stewart Guy and Todd Manning. Forest Resources Development Agreement and BC Ministry of Forests. Victoria, BC.

Wilson, S.M. and A.B. Carey. 2000. "Legacy Retention versus Thinning Influences on Small Mammals" in *Northwest Science* 74:131–145.

10 GLOSSARY

(BCMOF 2000a, b, c; WTCBC 1994)

Accumulations: Areas where residue and waste are concentrated, e.g., at landings and along roadsides.

Accuracy: Nearness of a measurement to the actual value of the variable being measured.

Allowed Stump Height: Higher of: 1) contractual stump height, 2) height specified in District Manager letter for heavy snow packs, 3) the minimum distance from the ground on the high side of a stump up to a point above a physical obstruction which allows for safe falling. Allowed stump height minus contractual stump height = avoidable piece.

Allowable Annual Cut (AAC): Rate of harvest determined by the Chief Forester for Timber Supply Areas (TSAs) and Tree Farm Licenses (TFLs), and by the District Manager for Woodlot Licenses (WLs), and the rate of harvest specified in a licence or in a management and working plan.

Avoidable Residue or Waste: Residue or waste wood volumes left on the ground that: a) could have been removed safely, b) were not physically obstructed, and c) were not inaccessible.

Biogeoclimatic Ecosystem Classification: Hierarchical classification scheme having three levels of integration: regional, local, and chronological; and combining climatic, vegetation, and site factors.

Biogeoclimatic Zone: A geographic area having similar patterns of energy flow, vegetation, and soils as a result of a broadly homogeneous macro-climate. British Columbia has 14 zones.

Breakage: Any piece meeting the minimum diameter of the cutting authority which is shorter than 3.0 m in length and broken at the large end or at both ends. Normal breakage is not usually recorded.

Bucking Waste: Any piece less than 3 m in length that has been cut at the large end, or at both ends. It has been cut through improper or careless bucking practices.

Call Grading: Procedure used to assign one of the Vegetation Resources Inventory (VRI) grades (modified coastal log grades) to standing and fallen timber. Grading is a hierarchical process. The grade extends up the tree as long as the grade rules allow. When a knot or other defect is encountered or the diameter can no longer support that grade, the grade changes for the next portion of the tree. (VRI)

Call Grading And Net Factoring: Processes used to assess timber quality and net tree volume. They are applied to the tree as the cruiser sees it. No attempt is made to predict grade based on falling breakage or any manufacturing process, or to predict volume loss without direct evidence (e.g., Vegetation Resources Inventory).

Chunk: Short piece of residue or waste that has resulted from end trimming logs, or from breaking logs during extraction operations.

Coast: Refers to the Vancouver Forest Region and the North Coast Forest District of the Prince Rupert Region.

Constrained: Part of the timber harvesting landbase subject to constraints on harvesting due to land use or integrated resource management objectives (e.g., riparian management areas, terrain sensitive areas, recreation areas, lake shore management areas, ungulate winter range)

Cutblock: A discrete area logged according to the harvesting plan and approved for the cutting authority issued under the license.

Cut Control: The Forest Service's procedures to monitor the volumes of timber harvested under a license through scaling and residue surveys, and the calculation and administration of the volumes remaining to be harvested under the license for the Cut Control period.

Cutting Authority: Refers to one of the following: Timber Sale License, License to Cut, Road Permit, or Cutting Permit issued under a Tree Farm License, Forest License, Timber License, or Woodlot License.

Cutting Specifications: Timber cutting specifications contained in the Minimum Utilization Standards of the cutting authority.

Danger Tree: Any tree that is hazardous to workers because of location or lean, physical damage, overhead deterioration of the limbs, stem or root system, or a combination of these.

Dispersed Stratum: In this stratum, residue and waste occur on the areas from which trees or logs have been removed and where sample plots can safely be established.

High Side (stumps): The position where the ground meets the stump on the uphill side, ignoring any root flare, obstacles, vegetation, and loose matter that have accumulated at the base of the tree. Length measurements usually start from 30 cm above this point.

Net Factoring: Estimating the net volume of sound wood (gross volume less decay) of variable log lengths. These net volumes are based on: 1) direct measurements (includes visual estimates and physical measurements); or 2) standard, rule-based deductions associated with loss indicators. (VRI)

Pencil Bucking: An imaginary sectioning of trees or CWD into potential logs. (VRI)

Log Grades: Log grades that are defined in the Scaling Regulation.

Minimum Utilization Standards: Standards of timber cutting and log utilization specified in the cutting authority.

Natural Disturbance Type (NDT): An area characterized by a natural disturbance regime. There are five natural disturbance types identified for managing biological diversity, two of which occur on the Coast.

Old Growth/Old Seral: Forests of a certain age or forests with the appropriate old forest attributes. Old growth and old seral are used interchangeably.

Precision: The closeness, to each other, of repeated measures of the same quantity, expressed as a sampling error or standard error of the sample estimate.

Reserves: Forested patches or individual trees retained during harvesting, or other forestry operations, to provide habitat, scenic, biodiversity or other values. They are long-term retention areas—generally one rotation or longer. Trees retained for a shorter term, such as seed or shelterwood trees, are not reserve trees. Reserve categories include: Wildlife Tree Patches from contributing landbase; uniformly distributed Wildlife Trees from contributing landbase; Wildlife Tree Patches from non-contributing landbase; Riparian Reserve; Gully Reserve; other stand-level reserves.

Residue: The volume of timber left on the harvested area that meets or exceeds the size requirements but is below the log grade requirements of the minimum utilization standards specified in the cutting authority. Residue volumes that are avoidable or unavoidable are subject to Cut Control charges.

Roadside Stratum: In this stratum, residue and waste occur along the roadsides to which logs have been yarded or skidded.

Sampling Error (SE): A measure of the variation among sample means is the standard error of the mean. It can be thought of as a standard deviation among sample means; it is a measure of the variation among sample means, just as the standard deviation is a measure of the variation among individuals. When we increase our confidence level above one standard deviation i.e., two standard deviations, we refer to the statistic as the sampling error.

Stratification: The process of delineating strata boundaries within a subpopulation, where each stratum has unique characteristics (timber type, logging contractors, season, or year logged).

Timber Supply Review (TSR): An assessment of how current forest management practices will affect the supply of wood available for harvesting over time. It also assesses how timber supply may be affected by changes in management practices and uncertainties about forest inventory and growth.

Trimming "Waste": Avoidable waste or residue that results from topping, slashing, bucking, and end-trimming in a manner that does not maximize utilization under the cutting specifications.

Utilization: Removal of timber from a cutblock in accordance with the utilization standards specified in the cutting authority.

Utility Grade logs: U and X grade logs.

Utility Grade and better logs: All grades other than Y and Z grade.

Variable Length Call Grading: Recognizes only a minimum length and allows the cruiser to pencil buck at grade changes rather than at predetermined log lengths. (VRI)

Variant: A subdivision of a biogeoclimatic subzone. Variants reflect further differences in regional climate and are generally recognized for areas slightly direr, wetter, snowier, warmer, or colder than other areas in the subzone.

Waste: Volume of timber left on the cutting authority area that should have been utilized in accordance with the timber utilization standards specified in the cutting authority. Waste volumes are subject to Cut Control charges.

Wildlife Tree or Wildlife Tree Patch: A tree or group of trees identified in an operational plan to provide present or future wildlife habitat.

APPENDIX A. DEFINITIONS OF SPECIES-SPECIFIC COASTAL LOG GRADES

Definitions from the provincial *Scaling Manual* (BCMOF 1999) and the *Logging Residue and Waste Measurement Procedures Manual* (BCMOF 2000a).

Grade	Definitions
M,L,K - Shingle	**Western redcedar (Cw)**
	K Grade Log: A log 3.8 m or more in length and 25 cm or more in radius or a slab 3.8 m or more in length, 25 cm or more in radius, and 38 cm or more in thickness, where at least 50% of the gross scale can be manufactured into shingles or shakes, and at least 75% of the shingles or shakes will be clear. Log requirements to make the grade include: no powder worm damage is per-mitted; logs 25 to 29 cm in radius must have the visible surface clear of knots and knot indications; logs 30 to 37 cm in radius must have at least 75% of the visible surface clear with knots or knot indications permitted on the upper 25% of two sides or the upper 50% of one side; logs 38 cm or over in radius must have at least 66 2/3% of the visible surface clear with knots or knot indications permitted on the upper 33 1/3% of two sides or the upper 66 2/3% of one side; maximum twist permitted over 30 cm in length is 4% of the diameter, up to a maximum deviation of 6 cm; bark seams, burls, butt rot, catface, checks, and other defects are permitted providing that the portion of the log free from these defects is sufficient to meet the grade rule.
	L Grade Log: A log 3.8 m or more in length and 19 cm or more in radius, or a slab 3.8 m or more in length, 19 cm or more in radius, and 26 cm or more in thickness, where at least 50% of the gross scale can be manufactured into shingles or shakes and a least 50% of the shingles or shakes will be clear. Log requirements to make the grade include: no powder worm damage is per-mitted; logs must have at least 50% of the visible surface clear, with knots and knot indications permitted on the upper 50% of two sides, or on all of one side; logs over 30 rads or slabs will be permitted if large knots are spaced so sufficient clear shingle blocks can be cut from the area between the knots to meet the grade rule. The large knots must have 30 rads (0.6 m) spacing to allow shingle blocks to be cut between them, and the blocks must be a quadrant; maximum twist permitted over 30 cm of length is 7% of the diameter, up to a maximum deviation of 8 cm; bark seams, burls, butt rot, catface, checks, and other defects are permitted providing the portion of the log free from these defects is sufficient to meet the grade rule.
	M Grade Log: A log 3.8 m or more in length and 19 cm or more in radius, or a slab 3.8 m or more in length, 13cm or more in radius, and 16 cm or more in thickness, where at least 50% of the gross scale can be manufactured into shingles and at least 25% of the shingles will be clear. Log requirements to make the grade include: no powder worm is permitted; logs must have at least 25% of the visible surface clear, with knots and knot indications permitted on the upper 75% of two sides, or all of one side and upper 50% of the other; logs over 25 rads, or slabs, will be permitted if large knots are spaced so sufficient clear shingle blocks can be cut from the area between the knots to meet the grade rule. The large knots must have 30 rads (0.6 m) spacing to allow shingle blocks to be cut between them, and the blocks must represent a quadrant; maximum twist permitted over 30 cm of length is 7% of the diameter, up to a maximum deviation of 8 cm; bark seams, burls, butt rot, catface, checks, and other defects are permitted providing the portion of the log free from these defects is sufficient to meet the grade rule.

continued

Grade	Definitions
D,F,G - High Grade	**E.g., Douglas-fir (Fd)** **D Grade Log:** A log 5 m or more in length and 38 cm or more in radius where at least 75% of the gross scale can be manufac-tured into merchantable lumber and at least 50% of that lumber will be clear. Log requirements to make the grade include: no conk or conk stain; pocket rot is allowable only if it is contained within a circle 1/3 the log radius measured from the pith; logs must have at least 90% of the visible surface clear with only a few well-spaced knots or knot indications permitted on the upper 10% of two sides or the upper 20% of one side; maximum twist permitted over 30 cm in length is 4% of the diameter up to a maximum deviation of 6 cm; no ring shakes are permitted in that part of the log between 8 cm and 20 cm of the bark; insect or worm holes other than ambrosia must not penetrate beyond the sap wood. **F Grade Log:** A log 5 m or more in length and 30 cm or more in radius where at least 75% of the gross scale can be manufactured into merchantable lumber and at least 25% of that lumber will be clear. Log requirements to make the grade include: no conk or conk stain; pocket rot is allowable only if it is contained within a circle 1/3 the log radius measured from the pith; logs 30 to 37 cm of radius must have at least 75% of the visible surface clear with only a few well-spaced knots or knot indications permitted on the upper 25% of the two sides or the upper 50% of one side; logs 38 cm and over in a radius must have at least 50% of the visible surface clear with only a few well-spaced knots or knot indications permitted on the upper 50% of two sides or upper 75% of one side; maximum twist permitted over 30 cm in length is 4% of the diameter at the top of the log to a maximum deviation of 6 cm; a ring shake that encircles half or more of the circumference of the ring is not permitted in that portion of the log between 4 and 10 rads of the bark. A ring shake within 4 rads of the bark is permitted only if that part of the log inside the shake is at least 30 rads and the log meets the rest of the grade rule; insect or worm holes other than ambrosia must not penetrate beyond the sap wood. **E.g., Sitka spruce (Ss)** **G Grade Log:** A log 4 m or more in length and 30 cm or more in radius where at least 75% of the gross scale can be manufac-tured into merchantable lumber and at least 25% of that lumber will be clear. Log requirements to make the grade include: no conk or conk stain; pocket rot is permitted if it is contained within a circle 1/3 the log radius, measured from the pith; logs 30 to 37 cm in radius must have at least 75% of the visible surface clear with only a few well-spaced knots or knot indications permit-ted on the upper 25% of two sides or the upper 50% of one side; logs 38 cm or more in radius (a) must have at least 50% of the visible surface clear with only a few well-spaced knots or knot indications permitted on the upper 50% of two sides or the upper 75% of one side, or (b) will permit large knots spaced so clear lumber, 2.5 cm in length, shop type, can be cut from the area be-tween the knots on at least 75% of the log's surface; logs 50 cm and over in radius will permit large knots spaced so clear lumber, 2.5 cm in length, shop type, can be cut from the area between the knots on at least 50% of the log's surface; maximum twist per-mitted over 30 cm of length is 4% of the diameter up to a maximum deviation of 6 cm. Ambrosia, burls, butt rot, and other de-fects are permitted providing the portion of the log free from these defects is sufficient to meet the grade rule.
B,C - Peeler	**E.g., Douglas-fir (Fd)** **B Grade Log:** A log 5.2 m or more in length and 30 cm or more in radius where at least 80% of the gross scale can be manufac-tured on a rotary lathe into veneer. **C Grade Log:** A log 5.2 m or more in length and 19 cm or more in radius where at least 80 % of the gross scale can be manufac-tured on a rotary lathe into veneer. Log requirements to make the grade include: no heart rot or conks; no fewer than six annual rings in each 2 cm of diameter; no knots over 4 cm, and knots or knot indications 4 cm or less in diameter must be well-spaced; maximum twist permitted over 30 cm of length is 7% of the diameter up to a maximum of 8 cm; insect or worm holes other than ambrosia must not penetrate be-yond the sap wood.

continued

Grade	Definitions
H,I,J - Sawlog	**E.g., Douglas-fir (Fd)** **H Grade Log:** A log (1) 5 cm or more in radius where at least 75% of the gross scale can be manufactured into lumber, AND (2) 25 cm or more in radius where at least 50% of the gross scale can be manufactured into lumber, and at least 65% of that lum-ber will be merchantable. Log requirements to make the grade include: no fewer than five annual rings in each 2 cm of diameter; maximum twist permitted over 30 cm in length is 7% of the diameter up to a maximum deviation of 8 cm; on logs 19 to 24 cm in radius there must be no more than well-spaced knots up to 5 cm in diameter on the upper 50% of the visible surface, or reasonably well-spaced knots up to 4 cm in diameter over all the visible surface; on logs 25 cm or over in radius there must be no more than occasional knots up to 8 cm in diameter on the upper 50% of the visible surface, or reasonably well-spaced knots up to 5 cm in diameter on the upper 66 2/3% of the visible surface, or reasonably well-spaced knots sup to 4 cm in diameter over all the visible surface. **I Grade log:** A log (1) 3.8 m or more in length AND a. 19 cm or more in radius where at least 75% of the gross scale can be manufactured into lumber, OR b. 25 cm or more in radius where at least 50% of the gross scale can be manufactured into lumber and at least 50% of that lumber will be merchantable OR (2) otherwise Grade code H, 5 m or more in length and 19 to 24 cm in radius, where less than 75% but at least 50% of the gross scale can be manufactured into lumber and at least 65% of that lumber will be merchantable. **J Grade log:** A log 5 m or more in length and 8 to 18 cm in radius where at least 75% of the gross scale can be manufactured into lumber and at least 50% of that lumber will be merchantable. Log requirements to make the grade include: specific knot size diameter for log radii that should not prevent the manufacture of the lumber requirements of the grade; maximum twist permitted over 30 cm of length is 10% of the diameter; burls, butt rot, shake, heart rot, and other defects are permitted providing the portion of the log free from these defects is sufficient to meet the grade rule.
U,X - Gang/Utility	**E.g., Douglas-fir (Fd)** **U Grade Log:** A log (1) 5 m or more in length AND a. 5 to 7 cm in radius where at least 75% of the gross scale can be manufactured into lumber, OR b. 8 to 18 cm in radius where at least 66 2/3% of the gross scale can be manufactured into lumber, OR 2) 3.8 m or more in length and 19 cm or more in radius where at least 50% of the gross scale can be manufactured into lumber and a least 35% of that lumber will be merchantable. Log requirements to make the grade include: specific maximum knot size diameters by log radii that should not prevent the manufacture of the lumber requirements of the grade; maximum twist permitted over 30 cm of length is 26% of the radius up to a maximum deviation of 13 cm; butt rot, butt shake, conk, checks, heart rot, and other defects are permitted providing the portion of the log free from these defects is sufficient to meet the grade rule. **X Grade Log:** A log 3 m or more in length and 5 cm or more in radius where at least 33 1/3% of the gross scale can be manufac-tured into lumber and at least 35% of that lumber will be merchantable. Log requirements to make the grade include: specific maximum knot size diameters by log radii that should not prevent the manufacture of the lumber requirements of the grade; logs 25 cm or over in radius will allow oversized knots up to a maximum of two per 3 m of log length; maximum twist permitted over 30 cm of length is 13% of the diameter up to a maximum deviation of 13 cm; butt rot, butt shake, conk, checks, heart rot, and other defects are permitted providing the portion of the log free from these defects is sufficient to meet the grade rule.
Live Y - Pulp	Logs and slabs cut from trees that were live or recently live, and that are lower in grade than Sawlog but better than Firmwood Reject.
Dead/Dry Y (Grade 5) - Pulp	Logs and slabs graded as Lumber Reject and cut from trees that were dead and dry when harvested. - To be classified as Dead/Dry the log must have one or more of the following characteristics: deteriorated cambium, loose or shedding bark, sap rot (encircling log end), wood borers, blue stain (encircling log end), deep checks (not weather checks).
Z - Firmwood Reject	All species. A log that is considered to have no commercial value, even for chips. A log where (1) heart rot or hole runs the whole length of the log being scaled, and the residual collar of the firmwood constitutes <50% of the gross scaled volume of the log OR (2) slabs or parts of slabs are <10 cm (5R) in thickness; OR (3) there is rot and the net length estimated by the scaler is <1.2 m; AND the net length includes the part of the log that is <10 cm (5R) in diameter.

APPENDIX B:

OPERATIONAL TRIAL TO EVALUATE THE USE OF MODIFIED HARVESTING PRACTICES IN COASTAL OLD-GROWTH STANDS TO MAXIMIZE COARSE WOODY DEBRIS LEVELS:

DESCRIPTIONS OF THE BUCKING, YARDING, AND LOADING PHASES

Prepared by
E. Redlin
Azmeth Forest Consultants Ltd.
Nanaimo, BC

February 28, 2002

TABLE OF CONTENTS

1.0 INTRODUCTION AND OBJECTIVES 48

2.0 SITE DESCRIPTION 48

3.0 DESCRIPTION OF METHODS AND PRACTICES 48

3.1 FALLING AND BUCKING METHODS 48
3.2 MARK TO LEAVE 50
3.3 YARDING AND LOADING 50

4.0 OBSERVATIONS 50

5.0 REFERENCES 50

APPENDIX B-1 GLOSSARY OF TERMS 59

APPENDIX B-2 WEYERHAEUSER'S SPECIFICATIONS CARD FOR FALLERS 60

APPENDIX B-3 EXPLANATION OF RESIDUE AND WASTE BILLING 61

APPENDIX B-4 WEYERHAEUSER'S GUIDE TO LOG IMPROVEMENT 62

1.0 INTRODUCTION AND OBJECTIVES

In 1999, under the guidance of the Coarse Woody Debris Working Group, the Vancouver Forest Region initiated an operational study to examine the feasibility of using modified bucking and yarding practices to maximize levels of coarse woody debris (CWD) in a dispersed harvesting setting in Coastal British Columbia.

The study comprised two components: the economic component was the responsibility of the Forest Engineering Research Institute of Canada (FERIC), and the dead-wood component was the responsibility of the Vancouver Forest Region.

Broadly stated, the objectives of the study were:

Economic component

- Monitor and compare the logistics of conventional yarding with yarding where non-merchantable/low-value wood is marked to be left on site.
- Estimate the costs of loading, transporting, and sorting non-merchantable/low value wood.
- Determine if marking of non-merchantable/low-value wood after falling but prior to yarding is an effective and economically feasible method to increase post-harvest CWD.

Dead-wood (CWD) component

- Quantify differences in CWD attributes in terms of pre- vs. post-harvest, and conventional vs. modified bucking and yarding practices.
- Identify attributes of potential sources of CWD prior to harvesting, and compare to the attributes of post-harvest CWD.
- Quantify volume and piece density of CWD removed through post-harvest salvage.

The study involved modifying the bucking and yarding practices currently used in Weyerhaeuser's helicopter operations for use in a ground-based harvesting setting, to:

1. maximize the retention of non-merchantable/low-value wood in the dispersed setting without affecting cut control volumes or increasing volumes of billable residue and waste, and
2. improve harvesting productivity and profitability by reducing hauling costs and dryland sort accumulations.

This report provides detailed descriptions of the operational bucking, yarding, and loading phases of the study; further details about the study's background and rationale can be found in an interim report prepared by the Vancouver Forest Region (Davis and Nemec 2001). A glossary of terms appears in **Appendix A**.

2.0 SITE DESCRIPTION

The harvesting site selected for study (Block No.: UA 1063F – 3057) is located up the Adams River in Tree Farm License 39 of Weyerhaeuser's North Island Timberlands, Kelsey Bay Operations. The opening is fairly homogeneous with respect to terrain, stand attributes, and site series. The forest is multistoried and consists of overmature, 25–30-m-high western hemlock (Hw) and amabilis fir (Ba) over intermediate BaHw layers, including advanced regeneration 2–10-m tall. Crown closure varies between 40 and 80%, structural diversity is average, and the density of snags is low. The site series is predominantly zonal.[1] Advanced regeneration and vaccinium (30–50%) dominate the understory layers. The timber is characterized by high decay, which has resulted in broken tops, conk, and basal scars.

3.0 DESCRIPTION OF METHODS AND PRACTICES

For the purposes of the study the harvesting site was divided in two, with the road as the dividing line.

1. The Conventional Block (CON) was harvested by conventional practices.

2. The Mark-to-Leave Block (MTL) was harvested by bucking, yarding, and loading practices that were modified from those used in Weyerhaeuser's helicopter harvesting operations. These modified practices involved:

a) Bucking on site to create higher value logs (CHVL). In this approach, non-merchantable/low-value wood (e.g., Z Grade) is bucked and left in the setting.

b) Marking Z and Y Grade wood for the purpose of leaving on site (MTL). A scaler marked the non-merchantable/low-value wood with paint after falling and bucking, but prior to yarding.

c) Yarding only those pieces that were not marked with paint.

d) Loading only those pieces that were not marked with paint.

The work was conducted by Weyerhaeuser's operational harvesting crews. Different falling crews were used in each block; however, there was some overlap with regard to yarding and loading operators. The Conventional Block was completed first, but this should not have had any effects on the results.

The crews were informed that a study was underway, and that they should follow standard procedures in the Conventional Block. The crews working in the MTL Block were given detailed instructions as to what would be required in the falling and bucking, mark-to-leave, and yarding and loading phases.

3.1 Falling and Bucking Methods

Quality-control supervisors worked approximately ten days with the fallers to ensure they were bucking to recover maximum log

[1] R.A. Harder and L.W. Apedaile, *Silviculture Prescription for BLK 3057*, November 27, 1998; Weyerhaeuser, BC Coastal Group, Nanaimo, BC; internal document.
M. Fidgeon, *Coarse Woody Debris (CWD) Pilot Study – Field Assessment of Potential Study Sites, November 21, 2000*; Vancouver Forest Region, BC Ministry of Forests, Nanaimo, BC; internal document.

value, and limiting the amount of cull attached to merchantable logs, and thereby increasing the volume of wood left on site as CWD without increasing the billable residue and waste volumes.

Prior to falling in the MTL Block, the fallers were given detailed instructions about bucking. The purpose and anticipated benefits were also reviewed. The fallers were instructed to assess for quality. The bucking was done so as to maximize value and quality of the logs while minimizing cull **(Figure 1)**. Log lengths were determined according to Weyerhaeuser's log specification card **(Appendix B)**. Steps to minimize cull included:

1. Long butt to remove defect or rot.
2. Buck out conk.
3. Remove shattered portions.
4. Buck out portions of the log that would be graded as Y or Z Grade wood.

The following section of the report describes the standards for applying these methods, and where applicable makes a comparison between the Conventional Block and the MTL Block.

3.1.2 Long Butt to Remove Severe Defect or Rot

Long butting refers to cutting a short length, usually <5 m, from the butt of the log. This is done to remove severe defect from the log or to remove excessive butt flare or deformity. This is a common practice in conventional harvesting operations.

The long butt should be >3 m long to be classified as a log and be graded as a Y or Z log. If the long butt is <3 m long it is classified as bucking waste, not graded, and billed at full stumpage in the Residue and Waste Survey.

Three common reasons for long butting are:

i) Butt rot (rot or hole) **(Figure 2)**.

If the rot or hole is >50% of measured butt diameter then the log should be long butted to a length >3 m.

ii) Water shake/checks **(Figure 3)**.

Water shake refers to the separation of the annual rings. Check refers to a split in the wood that runs at right angles to the grain. If the check or water shake is >50% of measured butt diameter then the log should be long butted to a length >3 m.

iii) Deformities **(Figure 4)**.

Deformities include forks and crooks.

3.1.3 Buck Out Conk

Conk is the fruiting body of a fungus. "A log with conk may show conk at the end of the log or may show conk in the knots. For logs with conk evident at the butt or top, the conk is presumed to run ½ the length of the log to a maximum of 6 m, or 3.6 m below the bottom knot showing conk and 2.4 m above the top knot showing conk or whichever is greater" (BCMOF 1999). This log is Y Grade for the affected length.

If the conk is evident on the butt, then it is common practice to long butt **(Figure 5)**; however, if the conk is evident in the mid section of the log and at knots, the conk may not be bucked out to ensure the specified log length is met **(Figure 6)**. In this case, the conk is bucked at the roadside or at the sort area.

If the conk occurs at the butt, then the rules outlined for long butting apply (Figure 2). If the conk is in the mid section of the piece, then the conk is bucked out. The rule is to cut 3.6 m below the bottom-most affected knot and 2.4 m above the top-most affected knot. This log section is graded as a Y or Z log in the Residue and Waste Survey, depending on the percentage of soundness. As demonstrated in Figure 5, bucking out conk can improve the value of the merchantable logs. However, these logs need to meet the minimum recovery specifications; for example, >3 m long and >17.5 cm at top. If the non-affected section is <3 m then the conk is not bucked out and the entire piece is a Y grade.

3.1.4 Remove Shattered Portions

Bole shatter may occur when a tree falls. Western redcedar, as well as clear, knot-free wood, are most susceptible to shatter.

In conventional falling, some shattered wood may be left on the piece to ensure the specified log lengths are met. At the log sort, this wood is bucked off and generally used as hog fuel rather than pulp because debarking small shattered pieces is difficult and expensive. If the shatter is somewhere in the middle of the piece, the standard is to remove 0.1 m on either side of the shatter, or buck through the shatter if it is still attached. This section is not recorded in a Residue and Waste Survey because it is part of the breakage percentage; for example, if it is <0.1 m long. For most Licensees, logs of higher grades are bucked to clean ends, while merchantable saw logs are bucked to a 60% shatter-free end. If a section of breakage <3 m in length is bucked from a log, there are several ways its volume may be accounted for:

1. Open Slash (Setting)—

a) If the large end is cut, the piece is classified as bucking waste and the volume is billed and charged against the allowable annual cut (AAC).

b) If the large end is broken, the piece is classified as breakage and not scaled. The volume is assumed to be included in the percentage of volume classified as breakage for AAC calculations.

c) A piece that is >3 m in length and is badly shattered, but, in the opinion of the residue and waste surveyor, will not withstand yarding and loading, can be called breakage and is not measured.

2. Accumulations—

a) Any piece with a cut end is classified as bucking waste and is both billable and chargeable.

In this study, in the MTL Block, pieces with shatter ≥2.5 m long,[2] or a fractured section ≥3 m long, was bucked and left on site. This piece is classified as Y Grade and is charged to the cut control but not billed. If the piece is <3 m long, it is classified as bucking waste and is billable on a Residue and Waste Survey.

As shown in **Figure 7**, bucking out the shatter can reduce the amount of cull that is handled throughout the processing system.

3.1.5 Buck Out Y or Z Grade Wood

A Y Grade log is lower in grade than Utility (X Grade) and higher in grade than Firmwood Reject (Z Grade). It is a chipper log used for pulp. The economics of using Y Grade wood for pulp depends upon the market conditions. Y Grade wood often has large and frequent knots, deformities, defect, and/or spiral that restrict the cutting of merchantable lumber **(Figure 8)**. This Y Grade wood was marked-to-leave in the MTL Block; its volume will be charged to the cut control but not billed.

Z Grade wood is not measured in a Residue and Waste Survey. Z Grade, or Firmwood Reject, wood is not usually used for pulp. This wood is typically <50% sound. (Refer to **Appendix C**.)

3.2 Mark to Leave

The mark-to-leave (or painting) phase, which occurred after falling and bucking were completed, but just prior to the yarding process, was done by licensed metric log scalers who were also residue and waste surveyors.

They walked the entire block, painting blue spots on any pieces that had been bucked off to minimize cull or because they were below the minimum recovery specifications. Only Y and Z Grade pieces were marked. These blue spots were approximately 20 cm^2 and were painted on several locations on the piece so as to be visible to the yarding engineer or the hooker even if the piece rolled.

3.3 Yarding and Loading

The yarding and loading crew received less instruction and supervision than the fallers received. The crew were asked not to yard or load any pieces with blue spots if possible. They were also asked not to load any obvious cull logs that were not painted. The pieces with blue paint were to be used as a reference for cull logs. And, if pieces with blue spots were inadvertently yarded, the crew were asked not to load them.

The yarding and loading crews were visited by the quality-control supervisor approximately every two weeks; in part, visits were not more frequent so as not to skew the study results.

4.0 OBSERVATIONS

Relative to the operational aspects of the modified bucking, yarding, and loading practices used in this study, the following observations were made:

1. The bucking practices have their greatest application in old-seral Coastal forests because the associated timber tends to have a high frequency of decay, waste, and breakage.

2. Fallers require on-site training and periodic monitoring to ensure that modified bucking practices do not create bucking waste and to ensure log grades are properly assigned.

3. The size, frequency, and colour of the paint marks need to be tested at the start of yarding because visibility is influenced by such factors as yarding distance, slope, and terrain.

4. Where visibility is limited (due to yarding method, deflection, and/or terrain), the yarding engineer requires the assistance of the second crew person to verify the presence or absence of paint marks.

5.0 REFERENCES

BC Ministry of Forests. 1999. *Scaling Manual, November 1999.* Revenue Branch. Victoria, BC. http://www.for.gov.bc.ca/revenue/manuals/scaling/Contents.htm

———. 2000a. *Provincial Logging Residue and Waste Measurement Procedures.* Revenue Branch, Victoria, BC.

Davis, G. and A. Nemec. 2001, in preparation. *Operational Trial to Evaluate the Effectiveness of Using Modified Bucking/Yarding Practices in Coastal Old-Growth Stands to Maximize Coarse Woody Debris Levels in the Setting.* Vancouver Forest Region, BCMOF. Nanaimo, BC. Interim internal report.

6.0 ACKNOWLEDGEMENTS

The author is grateful to Gerry Davis, Bruce Markstrom, and Kathi Hagan for their assistance in preparing this report.

[2] A 2.5-m length is a subjective length at which point at least 3 m is bucked off.

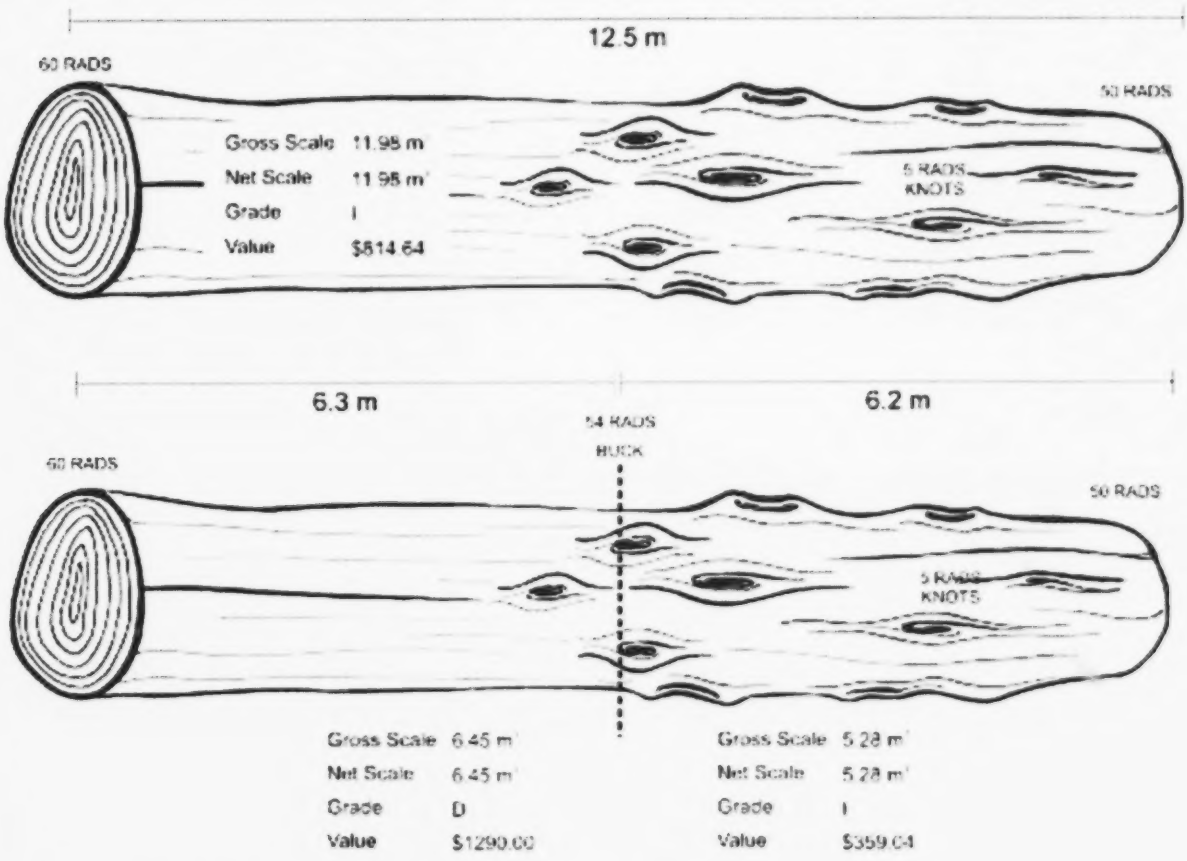


Figure 1. Increasing log value through modified bucking. [3]

[3] The illustrations of logs in this report/appendix are not to scale; they are provided for general reference only.

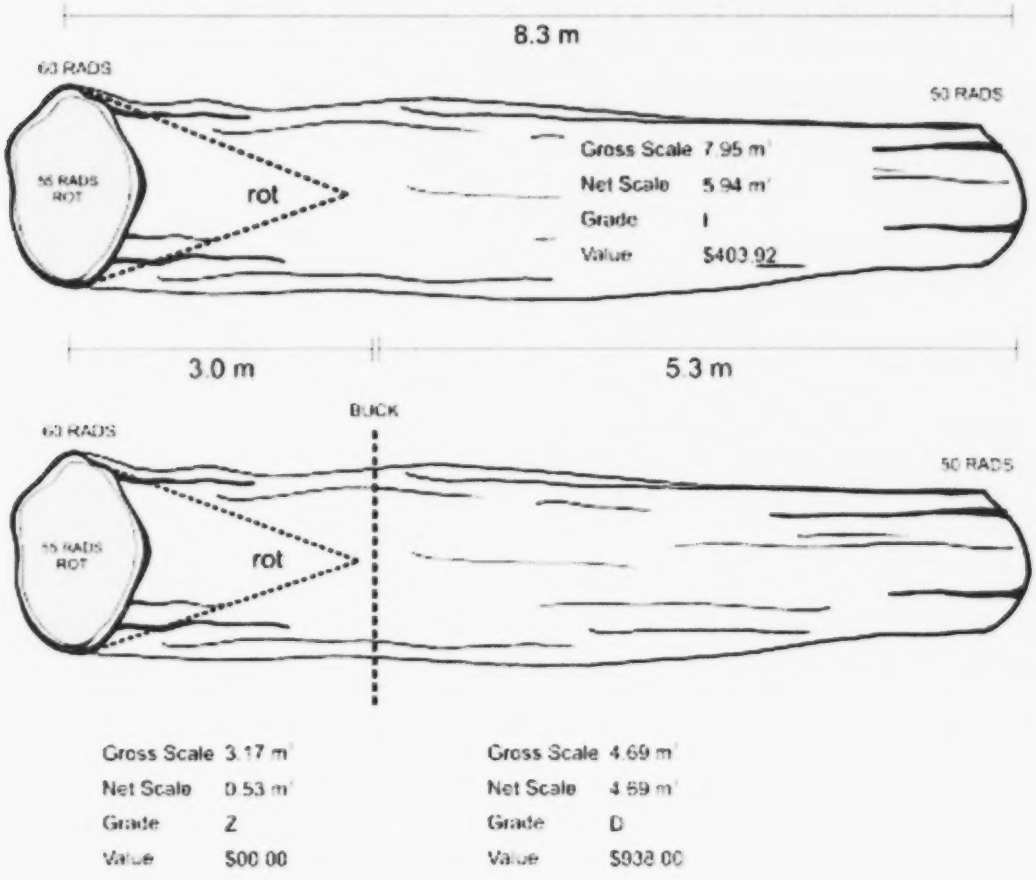


Figure 2. Using long butting to remove butt rot.

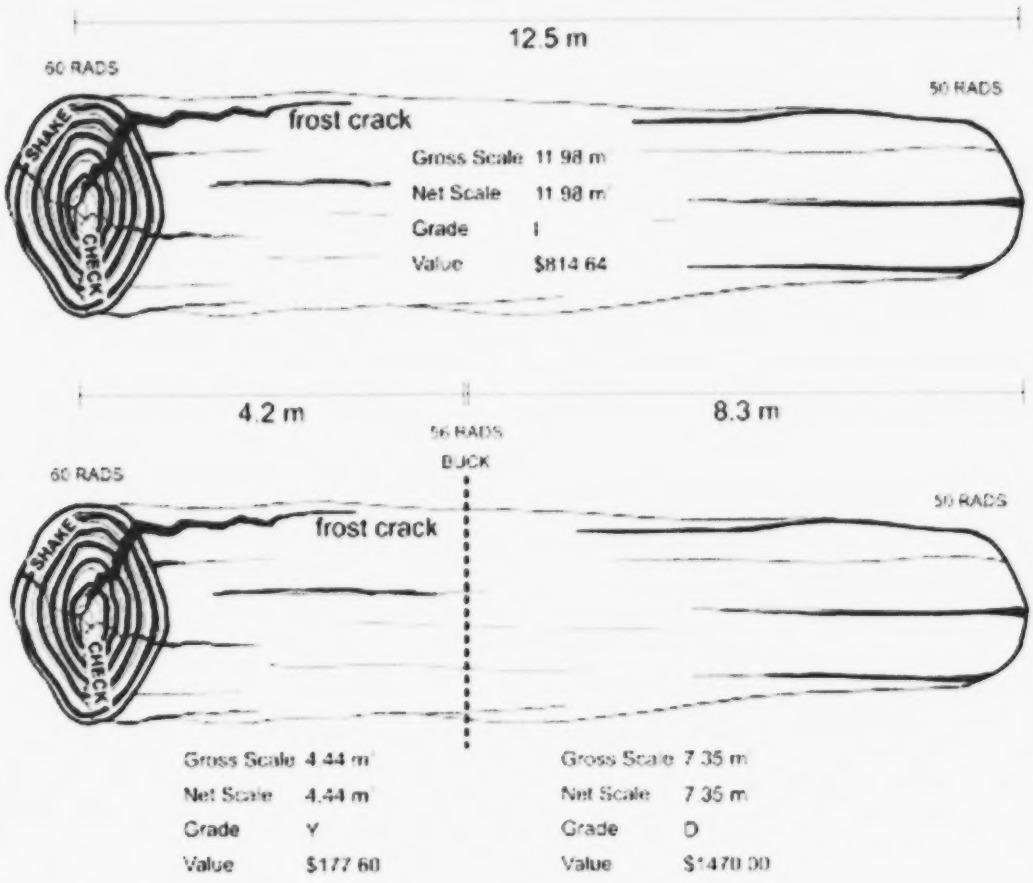


Figure 3. Using long butting to remove water shake/checks.

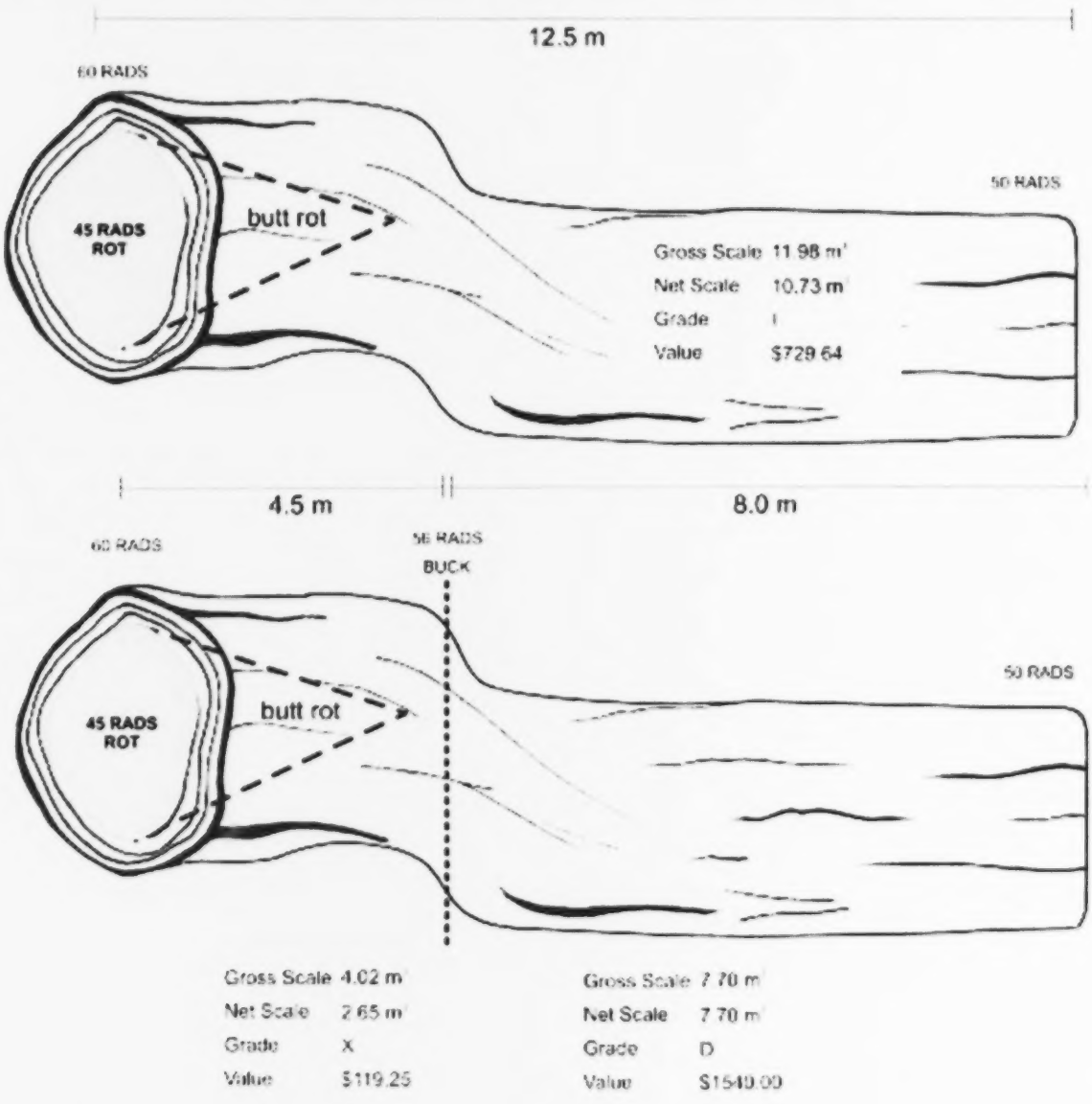


Figure 4. Using long butting to remove deformities.

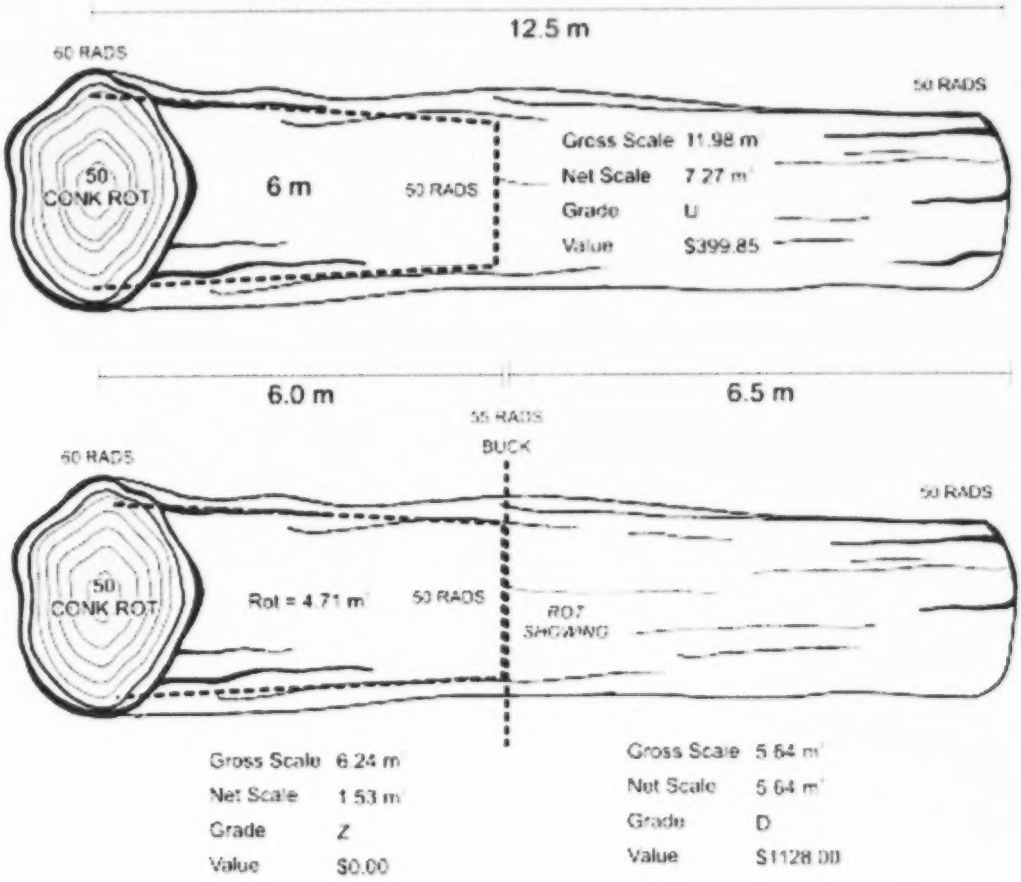


Figure 5. Using long butting to remove conk from the butt.

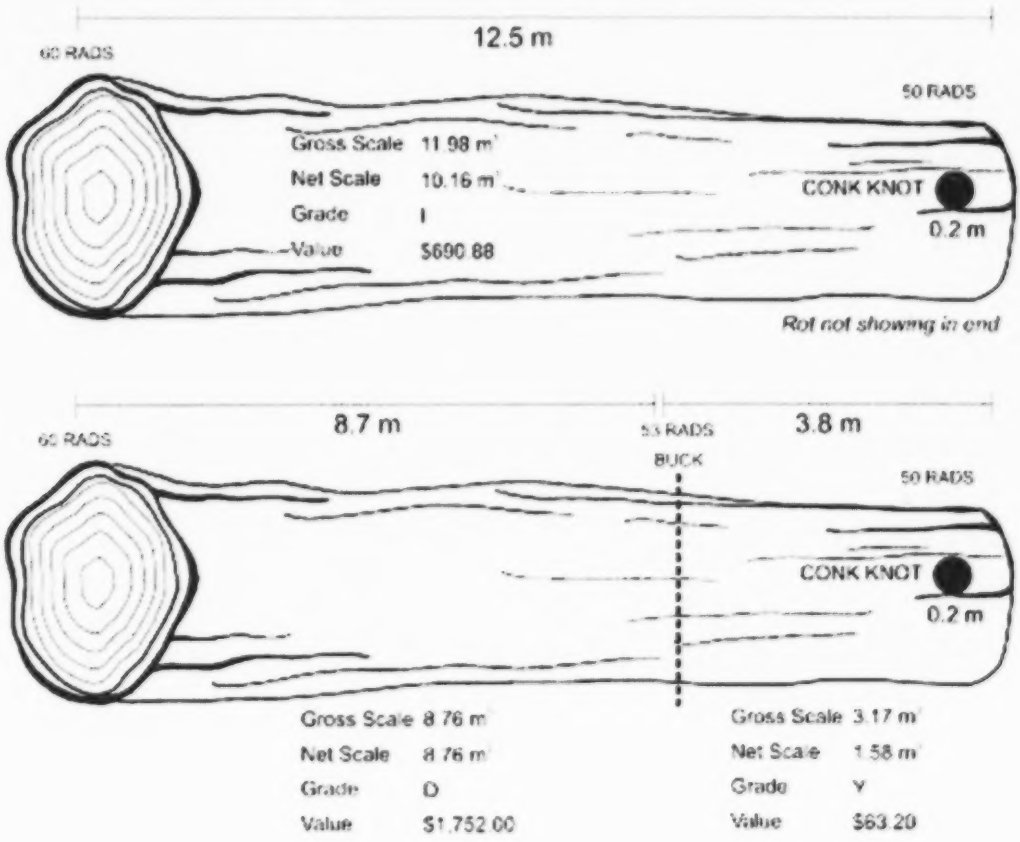


Figure 6. Using long butting to remove knots.

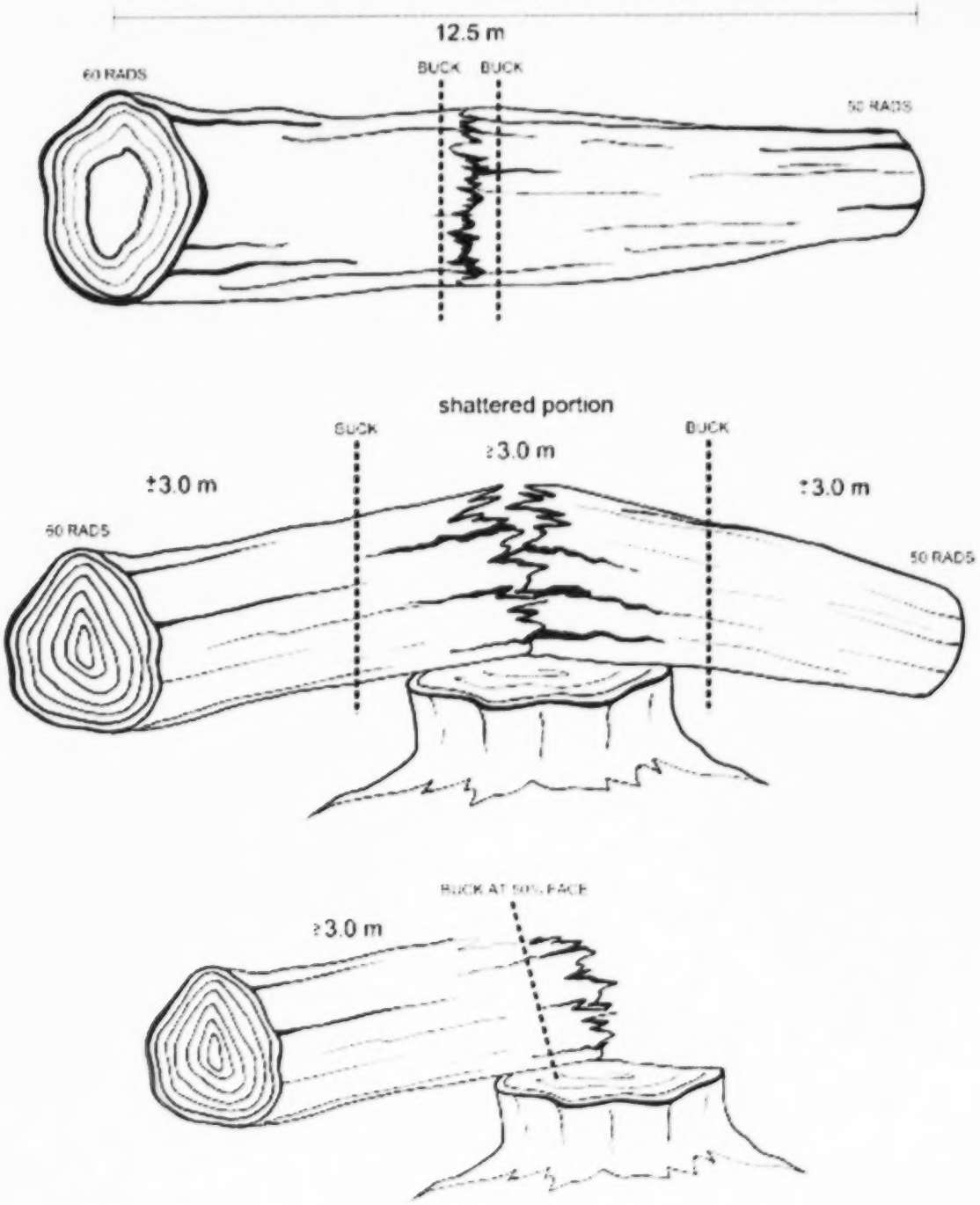


Figure 7. Using modified bucking to remove shatter.

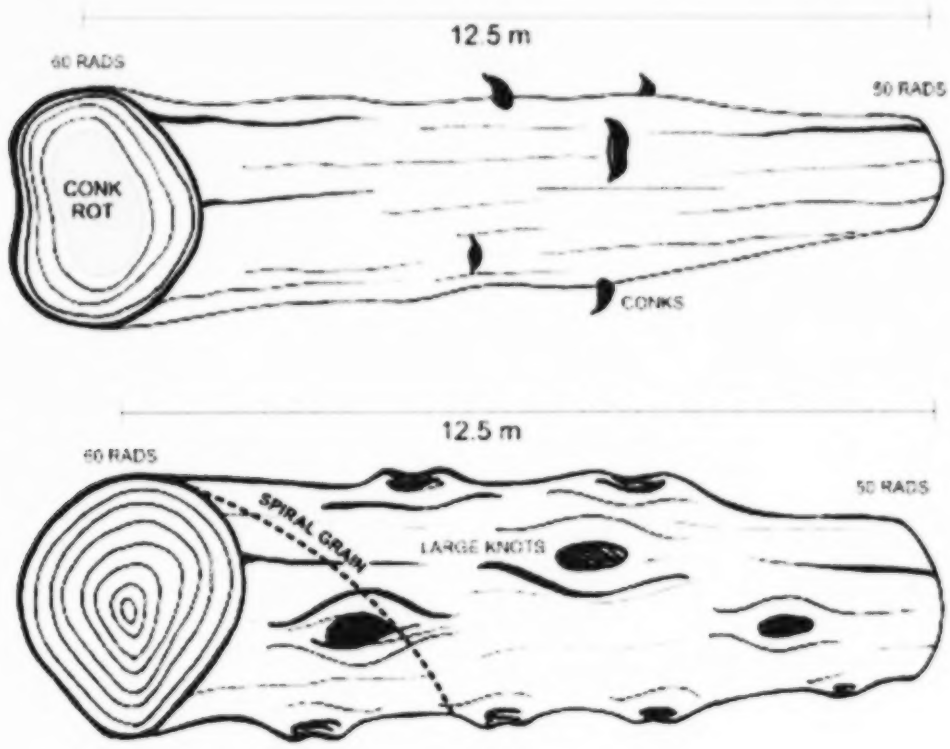


Figure 8. Y and/or Z grade pieces that are not recovered.

APPENDIX B-1: GLOSSARY OF TERMS

BCMOF—British Columbia Ministry of Forests.

BUCKING WASTE—Pieces of trees cut to less than the minimum utilization length (3.0 m) and >50% sound.

BULL BUCKER—The faller's foreman/supervisor.

BUTT CUT—The log closest to the stump. This cut can be identified by the undercut showing at the large or butt end.

BUTT ROT—Conical rot occurring in the base of a tree and found in the butt log after falling. If the log is <75% sound the faller/bucker should long butt at least 3 m.

CHASER—A person who works in the log landing and whose primary job is to unhook the chokers from the logs as they are landed at roadside. This person may help buck broken ends, etc.

CHECK—A split in the wood that runs at right angles to the annual rings.

CONK LOG—A log with conk showing at the end, or with conk knots on the log. The conk is presumed to run half the length of the log to a maximum of 6 m, or 3.6 m below the bottom-most knot and 2.4 m above the top-most knot or whichever is greater. This area of the log is Y Grade for the affected length.

CULL LOGS—Logs that are graded as either Y or Z Grade, as determined by the British Columbia metric grading rules.

DEFECT—Irregularities in the stem or structure of a log that impede the cutting of merchantable lumber or chips (e.g., rot, shake, crooks, forks, spiral grain, large or frequent knots).

HEART ROT—Cylindrical rot which can occur in any portion of a tree. If heart rot is >75% of the end volume, a minimum 3-m piece should be removed.

HOG FUEL—Waste wood/bark produced at the dryland sort, and/or cull logs, that are ground up and used as a supplementary fuel at pulp mills.

HOOKER—Head of the yarding operations; responsible for ensuring the yarder and loader are properly positioned, the rigging is set up for maximum safety and efficiency, and the overall running of the yarding operation.

LOG—Any section of the bole, or of the thicker branches of a felled tree, after trimming and cross cutting.

LONG BUTT—A short length, usually <5 m, cut from the butt log to reduce the extent of severe defect or to remove excessive butt flare or deformity.

MERCHANTABLE LOG—A log with knots that are small enough to facilitate good, strong, general-purpose lumber at least 2.5-m long and graded as better than Utility.

MINIMUM RECOVERY SPECIFICATIONS—In old-growth timber, this is a log which is ≥3.0 m long, ≥15 cm at the small end, and is X Grade or better. In second-growth timber, this is a log which is ≥3.0 m long, and ≥10 cm at the small end.

NET VOLUME—The firmwood volume of a piece of wood after deductions for rot and voids.

PULP LOG—There are two types of "pulp" logs:

1. A log that is an alpha Y Grade or chipper, based on BCMOF's metric log scaling rules.

or

2. A log that does not meet the industry's current sort requirements for a peeler, lumber, shingle, or saw log.

RADS—The common unit for measuring log diameter, as per BCMOF scaling protocol. 1 RAD equals 2 cm in diameter.

SAW LOG—A log from which lumber of merchantable dimensions can be cut.

SECOND CUT—This is the second log up the tree, although it may not be possible to tell a second cut from a third or fourth cut.

SLAB—A non-round (split) portion of the log, at least 10-cm thick and 10 cm in diameter.

TURN—One cycle of the yarding lines, for example, when the grapple travels from the yarder to the logs in the setting, grapples one or more, and returns to the landing.

WATER SHAKE—The separation of the annual rings in the end of a log.

X GRADE—A log ≥3 m long and ≥5 cm in radius where at least 33 and 1/3% of the gross scale can be manufactured into lumber, and at least 35% of that lumber will be merchantable. The net volume of X Grade and better logs scaled in a Residue and Waste Survey is billed to the Licensee and charged to the AAC.

Y GRADE (Chipper)—A log lower in grade than Utility [X] and higher in grade than Firmwood Reject [Z]. This log is not billable in a Residue and Waste Survey, but its net volume is charged to the AAC.

Z GRADE (Firmwood Reject)— 1. A log where:

a) Heart rot or a hole runs the entire length of the log and the residual collar of the firmwood constitutes <50% of the gross scale of the log,

or

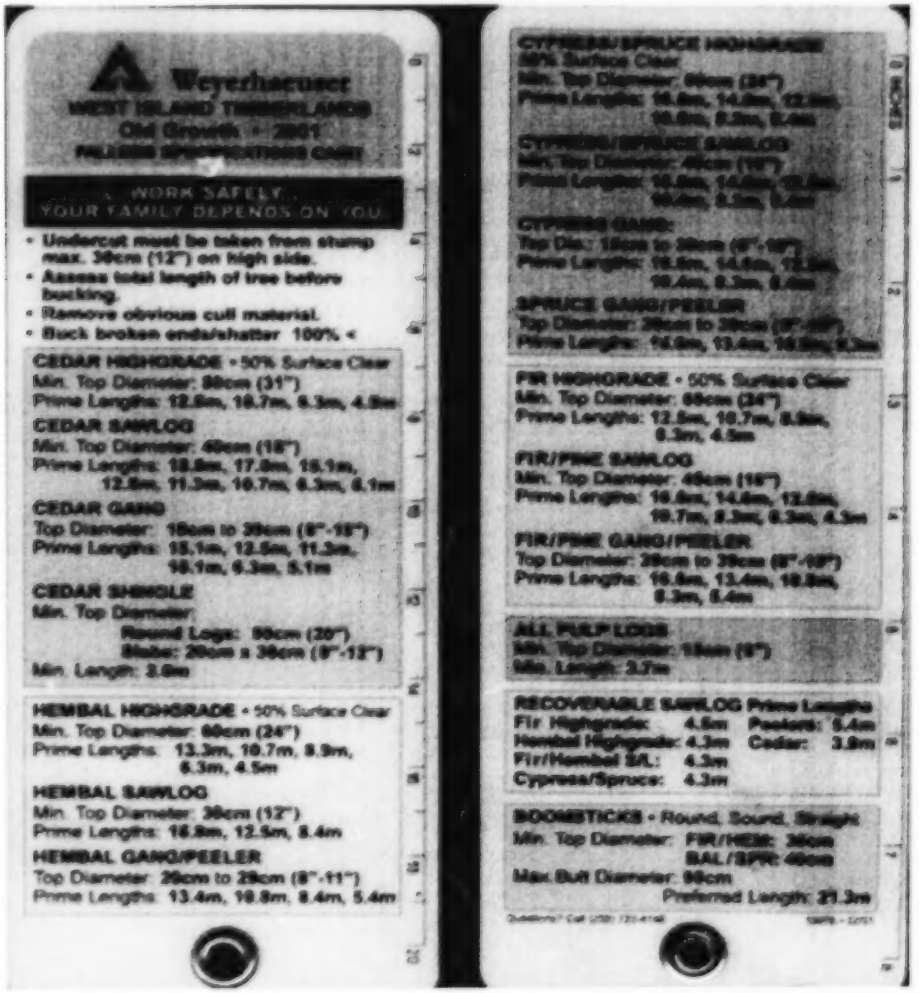
b) Rot is in the log and the scaler estimates the net length of the log to be <1.2 m,

or

c) Sap rot or charred wood exists and the residual firmwood is <10 cm in diameter at the butt end of the log.

2. That portion of a log that is <10 cm in diameter, or that portion of a slab that is <10 cm in thickness.

APPENDIX B-2:
WEYERHAEUSER'S SPECIFICATIONS CARD FOR FALLERS, WEST ISLAND TIMBERLANDS


Weyerhaeuser
WEST ISLAND TIMBERLANDS
Old Growth - 2001
FALLERS SPECIFICATIONS CARD
WORK SAFELY
YOUR FAMILY DEPENDS ON YOU
• Undercut must be taken from stump max. 30cm (12") on high side.
• Assess total length of tree before bucking.
• Remove obvious cull material.
• Buck broken ends/shatter 100% <
CEDAR HIGHGRADE • 50% Surface Clear
Min. Top Diameter: 80cm (31")
Prime Lengths: 12.8m, 10.7m, 8.3m, 4.9m
CEDAR SAWLOG
Min. Top Diameter: 40cm (16")
Prime Lengths: 18.8m, 17.8m, 15.1m, 12.8m, 11.3m, 10.7m, 8.3m, 6.1m
CEDAR GANG
Top Diameter: 18cm to 39cm (8"-15")
Prime Lengths: 15.1m, 12.5m, 11.3m, 10.1m, 6.3m, 5.1m
CEDAR SHINGLE
Min. Top Diameter:
Round Logs: 90cm (20")
Slabs: 20cm x 36cm (8"-13")
Min. Length: 3.6m
HEMBAL HIGHGRADE • 50% Surface Clear
Min. Top Diameter: 60cm (24")
Prime Lengths: 13.3m, 10.7m, 8.9m, 6.3m, 4.5m
HEMBAL SAWLOG
Min. Top Diameter: 30cm (12")
Prime Lengths: 16.8m, 12.5m, 8.4m
HEMBAL GANG/PEELER
Top Diameter: 29cm to 29cm (8"-11")
Prime Lengths: 13.4m, 10.8m, 8.4m, 5.4m
CYPRESS/SPRUCE HIGHGRADE
50% Surface Clear
Min. Top Diameter: 60cm (24")
Prime Lengths: 16.8m, 14.8m, 12.8m, 10.8m, 8.3m, 6.4m
CYPRESS/SPRUCE SAWLOG
Min. Top Diameter: 40cm (16")
Prime Lengths: 16.8m, 14.8m, 12.8m, 10.8m, 8.3m, 6.4m
CYPRESS GANG:
Top Dia.: 18cm to 39cm (8"-15")
Prime Lengths: 16.8m, 14.8m, 12.8m, 10.4m, 8.3m, 6.4m
SPRUCE GANG/PEELER
Top Diameter: 29cm to 39cm (8"-15")
Prime Lengths: 14.8m, 13.4m, 10.8m, 8.3m
FIR HIGHGRADE • 50% Surface Clear
Min. Top Diameter: 60cm (24")
Prime Lengths: 12.8m, 10.7m, 8.3m, 6.3m, 4.5m
FIR/PINE SAWLOG
Min. Top Diameter: 40cm (16")
Prime Lengths: 16.8m, 14.8m, 12.8m, 10.7m, 8.3m, 6.3m, 4.5m
FIR/PINE GANG/PEELER
Top Diameter: 29cm to 39cm (8"-15")
Prime Lengths: 16.8m, 13.4m, 10.8m, 8.3m, 6.4m
ALL PULP LOGS
Min. Top Diameter: 18cm (8")
Min. Length: 3.7m
RECOVERABLE SAWLOG Prime Lengths
Fir Highgrade: 4.6m Peelers: 5.4m
Hembal Highgrade: 4.3m Cedar: 3.6m
Fir/Hembal S/L: 4.3m
Cypress/Spruce: 4.3m
BOOMSTICKS • Round, Sound, Straight
Min. Top Diameter: FIR/HEM: 30cm
BAL/SPR: 40cm
Max.Butt Diameter: 90cm
Preferred Length: 21.3m
INCHES

APPENDIX B-3: EXPLANATION OF RESIDUE AND WASTE BILLING

In 1988, the BC Ministry of Forests (BCMOF) began a program of measuring the net volume and quality of harvesting debris. The material that was measured was charged to the allowable annual cut (AAC) and the avoidable portions were billed at the full stumpage rate to the Licensee. The Cutting Permit document defines the portion of trees that are recoverable, thus billable and avoidable waste.

In old-growth timber, a Licensee is usually required to recover that portion of a tree that is between a 30-cm-high stump and a 15-cm-diameter top. All portions of this tree that are X Grade or better and >3 m long, must be recovered.

In a Residue and Waste Survey, pieces other than stumps are classified either as logs or bucking waste. Logs must be graded as per the BCMOF alpha grades. The net volume of any log that is X Grade or better is charged to the AAC and is billed monetarily to the Licensee. Y Grade logs are recoverable at the Licensee's option. If live Y Grade logs are recovered, they are billed at $0.25/m^3$ and charged to the AAC. If the Licensee chose not to recover these Y grade logs, their volume is charged to the AAC but they are not billed. Logs which are Y Grade and come from a dead tree are Grade 5 and are not measured. Logs which are Z Grade or <50% sound are not measured at all.

Bucking waste is not allowed to be graded; as long as it is >50% sound and avoidable, the net volume is billed monetarily and charged to the AAC.

If a log is to have cull portions removed to upgrade its value, this can be done without affecting the cut control volume or increasing the billable volume. This is accomplished by removing only severe rot or defect from a log, and ensuring the length removed is >3 m long. These two requirements accomplish four things:

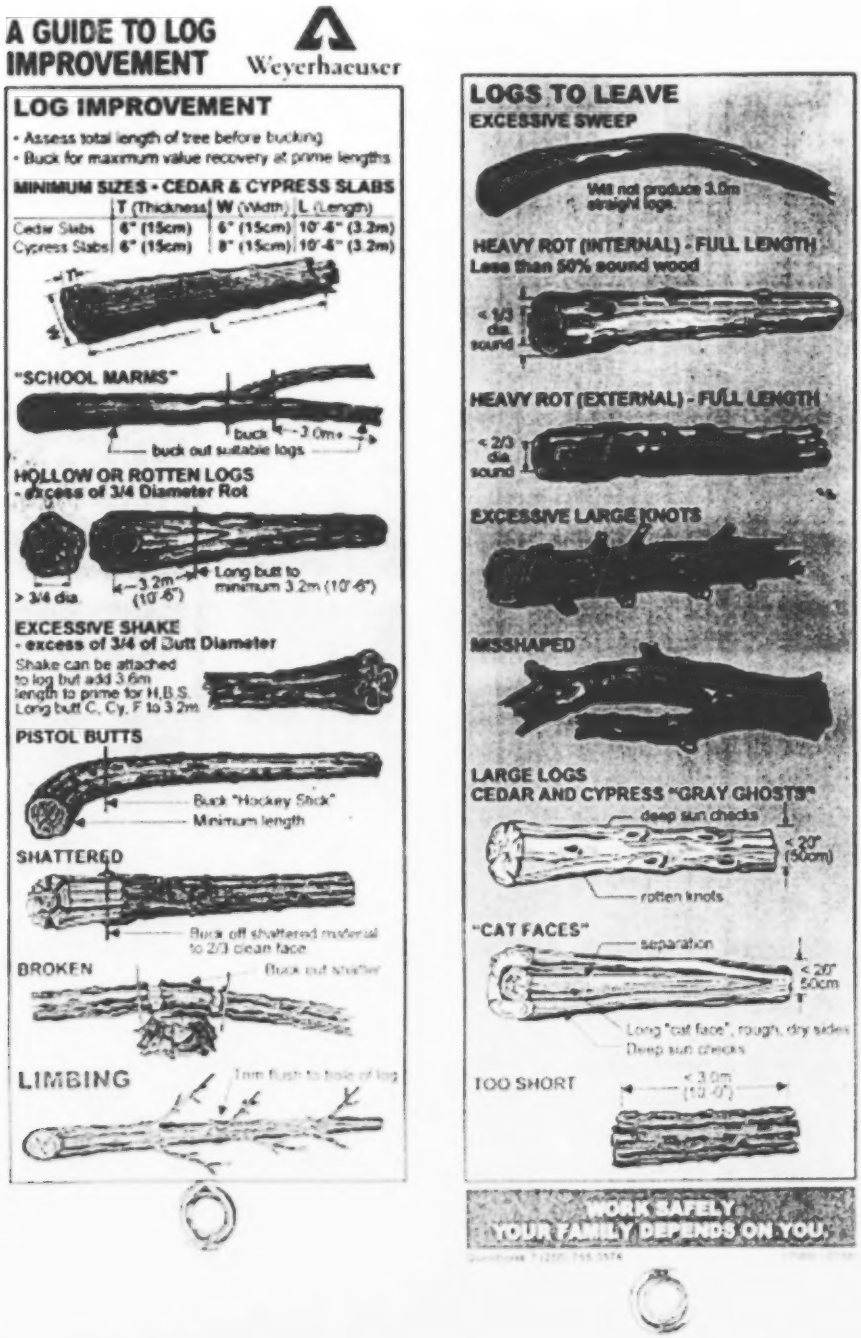
1. This length ensures the piece is a non-billable log (Y or Z Grade), and not bucking waste.

2. The parent log may be upgraded thereby, making it more valuable (see Figures 2–6).

3. Creates large sized CWD dispersed across the setting at little or no cost to the Licensee.

4. Reduces volume of cull logs and waste wood at the landing.

APPENDIX B-3:
WEYERHAEUSER'S GUIDE TO LOG IMPROVEMENT


A GUIDE TO LOG IMPROVEMENT
Weyerhaeuser
LOG IMPROVEMENT
• Assess total length of tree before bucking
• Buck for maximum value recovery at prime lengths
MINIMUM SIZES - CEDAR & CYPRESS SLABS
T (Thickness) W (Width) L (Length)
Cedar Slabs 6" (15cm) 6" (15cm) 10'-6" (3.2m)
Cypress Slabs 6" (15cm) 8" (15cm) 10'-6" (3.2m)
"SCHOOL MARMS"
buck
3.0m+
buck out suitable logs
HOLLOW OR ROTTEN LOGS
- excess of 3/4 Diameter Rot
> 3/4 dia
3.2m (10'-6")
Long butt to minimum 3.2m (10'-6")
EXCESSIVE SHAKE
- excess of 3/4 of Butt Diameter
Shake can be attached to log but add 3.6m length to prime for H.B.S. Long butt C, Cy, F to 3.2m
PISTOL BUTTS
Buck "Hockey Stick"
Minimum length
SHATTERED
Buck off shattered material to 2/3 clean face
BROKEN
Buck out shatter
LIMBING
1cm flush to base of log
LOGS TO LEAVE
EXCESSIVE SWEEP
Will not produce 3.0m straight logs.
HEAVY ROT (INTERNAL) - FULL LENGTH
Less than 50% sound wood
< 1/3 dia. sound
HEAVY ROT (EXTERNAL) - FULL LENGTH
< 2/3 dia. sound
EXCESSIVE LARGE KNOTS
MISSHAPED
LARGE LOGS
CEDAR AND CYPRESS "GRAY GHOSTS"
deep sun checks
< 20" (50cm)
rotten knots
"CAT FACES"
separation
< 20" 50cm
Long "cat face", rough, dry sides
Deep sun checks
TOO SHORT
< 3.0m (10'-0")
WORK SAFELY
YOUR FAMILY DEPENDS ON YOU

APPENDIX C

SUMMARY OF CWD DENSITY AND VOLUME STATISTICS FOR BOTH STUDY BLOCKS, USING LENGTH AND DIAMETER CLASSES FROM THE LITERATURE

Plot (no.)	Diameter Class (cm)	Length Class <1 m (no. pieces/ha)	<1 m (m^3/ha)	1-3 m (no. pieces/ha)	1-3 m (m^3/ha)	3-7 m (no. pieces/ha)	3-7 m (m^3/ha)	<7 m (no. pieces/ha)	<7 m (m^3/ha)	<5 m (no. pieces/ha)	<5 m (m^3/ha)	<10 m (no. pieces/ha)	<10 m (m^3/ha)	Total (no. pieces/ha)	Total (m^3/ha)
23	≤20	134.8 ± 38.0	1.0 ± 0.3	189.2 ± 42.1	3.5 ± 0.7	31.1 ± 6.2	1.8 ± 0.4	5.1 ± 2.5	0.7 ± 0.4	9.9 ± 3.3	1.1 ± 0.4	1.0 ± 0.9	0.2 ± 0.2	347.9 ± 55.6	6.7 ± 1.1
	20.1- 40	77.5 ± 22.3	0.7 ± 0.2	38.3 ± 7.1	2.9 ± 0.5	34.3 ± 4.2	5.1 ± 0.6	36.8 ± 6.7	13.1 ± 1.9	48.5 ± 7.0	15.3 ± 2.0	22.0 ± 5.6	9.4 ± 1.7	181.6 ± 30.5	21.2 ± 2.5
	40.1 - 80	2.9 ± 0.9	0.2 ± 0.1	32.1 ± 5.6	7.4 ± 1.3	42.9 ± 5.1	21.8 ± 3.5	40.1 ± 4.1	80.7 ± 13.8	54.2 ± 4.9	90.4 ± 14.3	27.6 ± 3.4	68.7 ± 12.7	113.7 ± 10.6	108.8 ± 15.7
	>80	0.0 ± 0.0	0.0 ± 0.0	2.0 ± 1.0	0.5 ± 0.3	9.2 ± 2.2	11.1 ± 2.7	15.7 ± 2.4	67.6 ± 13.4	19.7 ± 2.7	73.2 ± 13.4	11.7 ± 1.9	59.1 ± 11.9	26.8 ± 2.9	79.2 ± 13.7
	15 - 30	120.2 ± 36.5	1.1 ± 0.4	102.8 ± 23.9	2.8 ± 0.5	43.9 ± 6.2	3.9 ± 0.7	28.3 ± 6.7	6.9 ± 1.6	41.5 ± 7.9	8.5 ± 1.6	11.6 ± 4.0	3.7 ± 1.2	281.7 ± 45.5	14.3 ± 2.1
	≤30	185.4 ± 43.3	1.4 ± 0.4	214.7 ± 42.4	4.7 ± 0.8	51.4 ± 7.0	4.2 ± 0.7	28.3 ± 6.7	6.9 ± 1.6	41.8 ± 8.0	8.5 ± 1.6	11.6 ± 4.0	3.7 ± 1.2	465.2 ± 60.4	16.7 ± 2.3
	30.1 - 60	28.7 ± 13.8	0.4 ± 0.2	32.2 ± 4.9	5.2 ± 0.8	41.8 ± 3.8	12.8 ± 1.2	32.1 ± 4.8	28.9 ± 3.9	43.2 ± 4.8	33.3 ± 4.0	23.9 ± 4.6	23.7 ± 4.0	129.4 ± 16.8	46.4 ± 4.4
	40.1 - 60	1.7 ± 0.8	0.1 ± 0.0	19.3 ± 4.2	3.5 ± 0.7	27.8 ± 3.2	10.1 ± 1.2	18.5 ± 2.3	22.1 ± 3.6	26.7 ± 2.3	25.5 ± 3.7	12.6 ± 2.3	17.8 ± 3.8	65.1 ± 6.2	35.2 ± 4.1
	>60	1.2 ± 0.6	0.1 ± 0.1	14.7 ± 3.3	4.4 ± 1.2	24.3 ± 3.7	22.8 ± 4.1	37.4 ± 4.7	126.2 ± 22.7	47.2 ± 5.5	138.1 ± 23.4	26.7 ± 3.9	110.1 ± 19.5	75.5 ± 8.1	152.8 ± 24.3
	30 - 50	27.8 ± 13.6	0.4 ± 0.2	25.7 ± 4.2	3.4 ± 0.6	31.9 ± 3.5	8.1 ± 1.0	23.5 ± 4.5	14.9 ± 2.2	32.7 ± 5.0	18.2 ± 2.4	17.3 ± 4.3	12.1 ± 2.1	103.9 ± 17.1	26.1 ± 2.7
	50 - 80	2.5 ± 0.9	0.2 ± 0.1	23.2 ± 4.0	6.2 ± 1.1	32.0 ± 4.6	18.9 ± 3.5	33.6 ± 4.1	75.3 ± 14.0	44.5 ± 4.9	83.9 ± 14.5	23.3 ± 3.4	64.6 ± 12.9	88.8 ± 9.1	99.6 ± 16.0
	>50	2.1 ± 0.8	0.2 ± 0.1	23.0 ± 3.8	6.3 ± 1.2	36.8 ± 5.2	27.9 ± 4.5	47.6 ± 5.2	140.9 ± 22.8	60.7 ± 6.0	154.2 ± 23.4	33.8 ± 4.2	121.9 ± 19.3	107.0 ± 9.5	174.4 ± 24.6
	Total	215.3 ± 48.9	1.9 ± 0.4	261.6 ± 41.4	14.2 ± 1.6	117.4 ± 9.8	39.8 ± 4.6	97.8 ± 8.9	162.0 ± 23.1	132.2 ± 11.1	180.0 ± 24.0	62.3 ± 7.6	137.4 ± 19.9	670.0 ± 70.1	215.9 ± 24.9